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SOLARTRON

Instruction Manual

for

LF Resolved

Component Indicator

VP253.2

Type VP253.2

VP 253.2

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THE SOLARTRON ELECTRONIC GROUP LTD
Thames Ditton, Surrey, England

THIS SPECIFICATION IS APPROVED
FOR USE IN THE CALIBRATION OF
COMPANY INSTRUMENTS.
3
CALIBRATION DEPARTMENT
QC FACILITIES
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INSTRUCTION MANUAL

FOR

L.F. RESOLVED COMPONENT INDICATOR

MODEL VP.253.2

PREFACE

Of recent years there has been an increased tendency to employ closed loop feedback control, this tendency being equally apparent in the fields of mechanical, electrical and electronic engineering. Whatever the field of application, the designer is, in almost every case, faced with the same basic problem, namely: that of providing the stiffest possible control over the working frequency range consistent with freedom from oscillation or under-damped response, outside the working frequency range. Such design work demands a full knowledge of the transfer function of each element employed in the control loop.

The usual method of transfer function determination is to excite the unit under test at a number of fixed frequencies covering the interested frequency range, using a constant input amplitude. The output amplitude and phase angle is noted in each instance, and these results are then recorded on polar co-ordinated paper to form what is now universally known as a Nyquist diagram. The Resolved Component Indicator is ideally suited to this method of measurement. Provision is made for two input voltages—one is known as the reference voltage, and the other as the signal voltage. Two 6-in. scale-length meters are provided, and the function of these is to separately indicate, in terms of true voltage, the resolved components of the signal input which are ' in phase with ' and ' at 90° to ' the reference input voltage. This resolved component presentation permits direct plotting of a Nyquist diagram on ordinary linear graph paper, thus eliminating the need for polar co-ordinate paper. A very important feature of the Resolved Component Indicator is that the meter indications are to a first order, independent of harmonic or spurious frequency content of the signal voltage, providing the reference voltage employed is itself free from such quantities.

There is scope for application of the Resolved Component Indicator wherever phase conscious measurement is required over the frequency range 0·1 c/s to 1 Kc/s, e.g., transformer testing, dynamic balancing, simulator circuits, magnetic core material comparison tests, etc.

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SECTION 1

PERFORMANCE SPECIFICATION

1. General
This instrument will indicate, by means of two centre-zero 6-in. scale meters, the resolved components of a signal voltage with respect to the applied reference energisation.

2. Frequency Range
Nominal range 0·5 c/s to 1 Kc/s.

3. Accuracy of Indication
$\pm 3\%$ of full scale on all ranges.

4. Signal Voltage Ranges
Full scale ranges of 50 mV, 150 mV, 500 mV, 1·5 V, 5 V, 15 V, 50 V and 150 V with either balanced or unbalanced input.

5. Signal Input Resistance
10 MΩ unbalanced.
20 MΩ balanced.

6. Reference Input
Four phase reference energisation is required, each phase having a level of 10 V r.m.s. with respect to a virtual earth.

7. Reference Input Resistance
6·2 MΩ per phase.

8. Harmonic and Unrelated Frequency Discrimination
Better than 40 db.

9. Mains Requirements
90–130 V and 200–240 V 40/60 c/s with a total consumption of 215 V.A. (205 watts).

10. Presentation
Standard rack panel 19 in. × 12¼ in. high, but mounted on a ' Solartron ' bench type case.

SECTION 2

PRINCIPLES OF OPERATION

The Resolved Component Indicator displays the ' in phase ' and ' quadrature ' components of an A.C. signal with respect to a related reference voltage. The equipment comprises a series of signal amplifiers and reference amplifiers interconnected as shown in the block diagram (Fig. 1). These amplifiers drive two special bridge connected thermocouple meters, which are the phase-discriminating circuit elements.
The circuit of one of these meters is shown in Fig. 2.

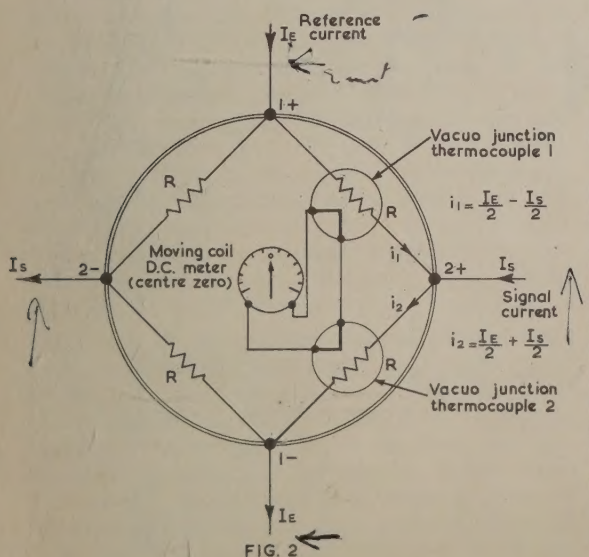


FIG. 2

A balanced reference voltage, either ' in phase ' or ' quadrature,' drives the energising current through the meter, and a balanced signal voltage drives the signal current.* It can be shown that with this system, the meter indication is directly proportional to the component of the signal which is in phase with the reference voltage, and in the ideal case there is no indication from spurious frequencies, harmonics or noise signals which are not simultaneously present in the reference signal.
Referring again to Fig. 1, the balanced input signal passes through a matched pair of input attenuators to two cathode followers which drive further simple ladder attenuators. The outputs from the 0° and 180° attenuators then pass through a pair of amplifiers, the 0° having a gain of 11·6 and the 180° having a gain of — 11·6. The resultant amplified signals, which are in phase, are added in a pair of matched resistors to give common mode rejection. The summation signal is A.C. coupled into another stage of amplification which is succeeded by the meter drive and image meter drive amplifiers which supply signal current to both meters. When the meter drive signal exceeds a preset maximum, equivalent to $\sqrt{2} \times$ the in-phase signal to give full-scale deflection on the reference meter, an overload detector operates, indicating that the device is operating in a non-linear fashion.
When a single-ended signal is used, the balanced–unbalanced signal is switched to unbalanced and the 180° input is virtually short-circuited.
A four-phase reference signal is required, and each phase passes through a cathode follower which is A.C.

* See Appendix A.

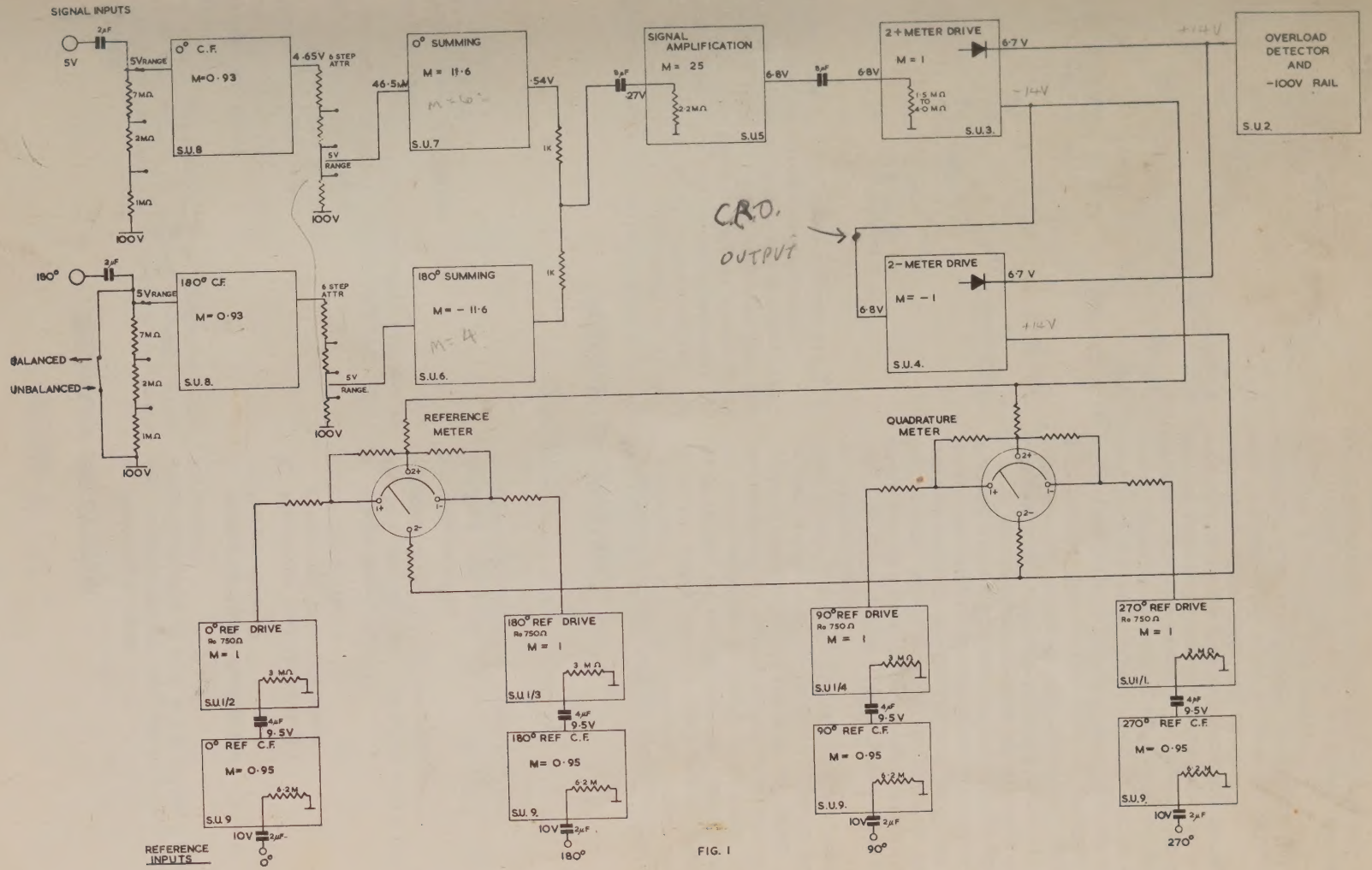

SIGNAL INPUTS
2μF
5V
5V RANGE
7MΩ
2MΩ
1MΩ
100V
0° C.F.
M=0·93
S.U.8
4·65V
6 STEP ATTR
5V RANGE
100V
0° SUMMING
M = 11·6
S.U.7
46·5kΩ
·54V
1K
SIGNAL AMPLIFICATION
M = 25
S.U.5
·27V
2·2MΩ
6·8V
2+ METER DRIVE
M = 1
1·5 MΩ TO 4·0 MΩ
S.U.3.
6·7 V
+14V
-14V
OVERLOAD DETECTOR AND -100V RAIL
S.U.2
C.R.O. OUTPUT
180°
2μF
5V RANGE
7MΩ
2MΩ
1MΩ
100V
BALANCED
UNBALANCED
180° C.F.
M= 0·93
S.U.8.
6 STEP ATTR
5V RANGE
100V
180° SUMMING
M = - 11·6
S.U.6.
1K
2- METER DRIVE
M = - 1
S.U.4.
6·8V
6·7 V
+14V
REFERENCE METER
QUADRATURE METER
0° REF DRIVE
Ro 750Ω
M = 1
3 MΩ
S.U.1/2
4μF
9·5V
0° REF C.F.
M= 0·95
6·3M
S.U.9
10V
2μF
0°
REFERENCE INPUTS
180° REF DRIVE
Ro 750Ω
M = 1
3 MΩ
S.U.1/3
4μF
9·5V
180° REF C.F.
M= 0·95
6·3M
S.U.9.
10V
2μF
180°
90° REF DRIVE
Ro 750Ω
M = 1
3 MΩ
S.U.1/4
4μF
9·5V
90° REF C.F.
M= 0·95
6·3M
S.U.9.
10V
2μF
90°
270° REF DRIVE
Ro 750Ω
M = 1
3 MΩ
S.U.1/L
4μF
9·5V
270° REF C.F.
M= 0·95
6·3M
S.U.9.
10V
2μF
270°

FIG. 1

coupled to a unity gain meter drive amplifier. The 0° and 180° phases drive the reference meter, and the 90° and 270° phases drive the quadrature meter.

There are three A.C. couplings in the signal channel which will give rise to some phase shifts at very low frequencies. To compensate for this, two A.C. couplings have been incorporated in each reference channel. This results in approximately equal phase shifts in the signal and reference channels, and negligible loss of accuracy down to 0·1 c/s.

SECTION 3

OPERATING INSTRUCTIONS

On receipt of the instrument, open the small door in the bottom rear corner of the right-hand side of the case. Extract two coaxial leads and one four-phase reference lead. Withdraw the mains cable as required, and insert it in the slot beside the door. Check that the mains selector panel is correctly set to the nominal supply voltage, close the door.

The unit requires a four-phase reference supply of 10 V r.m.s. per phase which is obtainable from either the Solartron L.F. Decade Oscillator Model OS.103 or the Solartron Mechanical Reference Generator Model JX.603. Connect this supply in correct phase sequence to the reference input terminals, or use the four-core cable provided.

When the Resolved Component Indicator has been placed in the position in which it is intended for use, the mechanical zero adjustments for the two meters should be correctly set before the instrument is switched on.

Switch on the instrument and allow approximately 10 minutes to warm up. Check the meter zero's and, if necessary, adjust the meter datum potentiometers. Connect the instrument to the signal to be measured, and select BALANCED or UNBALANCED as required.

It is recommended that one earth connection only be made from the work on test to the Resolved Component Indicator earth terminal, in order to eliminate the possibility of error voltages arising from loop currents. Further, when either the work, or any auxiliary equipment connected to the work, has a direct earth connection, the Resolved Component Indicator should be set to 47Ω earth. This connects a 47Ω resistor between the negative rail of the instrument and the mains earth, hence, eliminating once again a possibility of loop current. When the equipment connected to the Resolved Component Indicator is fully isolated, the above-mentioned switch should, of course, be set for direct earth.

The choice of using either shielded or unshielded connecting wires will, in each case, be dependent upon the frequency, impedance and relative amplitude levels in the circuits supplying the Resolved Component Indicator. When operating at low level on high-impedance systems, it is essential that shielded cable be employed, otherwise pick-up signals in excess of the working signals may fully load the Resolved Component Indicator. On the other hand, if shielded cable is employed at high frequency the stray capacitance of the cable may well result in unwanted phase shift in the circuit under test. In every case, therefore, the above-mentioned points should receive careful consideration.

When shielded cable is employed, it is advised that the braiding be cut back at the free ends and a single earth wire be run from the Resolved Component Indicator earth terminal, thus protecting against loop currents.

When the signal to be measured is superimposed on a large quiescent voltage, the charging of the input time constant will paralyse the instrument for several minutes. To reduce this paralysis time to reasonable proportions, a PRIME position is provided on the sensitivity switch. This should be selected before switching to the required sensitivity range.

The drive amplifiers for the thermocouple wattmeters have overload protection which ensures that application of even the most excessive overload will not result in burn out. However, the instrument should not be left for more than 30 seconds with either indicating meter reading in excess of full scale, otherwise ageing of the thermocouple elements may result, with a consequent slight change in sensitivity.

Overload conditions may exist under conditions of poor signal-to-noise ratio or when both meters are operating near full scale in the presence of either harmonics or noise. Any overload, however short the duration, will be indicated by the overload neon, and steps should be taken to reduce the sensitivity range. The presence of an overload will adversely affect the accuracy of the instrument.

After a severe overload, the normal recovery time of the instrument is excessive. To reduce this, press the reset button and hold for a few seconds.

The wattmeters employed in the Resolved Component Indicator utilise thermocouple elements and, consequently, there will be a loss of sensitivity with increasing ambient temperature.

The extent of the sensitivity error is in the order of 0·2% per °C. The instruments are calibrated at a nominal room temperature of approximately 25°C and, consequently, operation at a temperature of 35°C will give an error in the order of 2%.

This temperature error applies only as far as absolute voltage measurement is concerned, and where transfer function is to be plotted its effect will be negligible. The usual procedure for testing is to apply a constant input voltage to the system under test, as determined by the oscillator output attenuator, and to plot at a

number of suitably chosen frequencies the resolved components of the voltage present at the selected point in the test system. Providing that the input voltage for the work is maintained constant throughout the test, results may be directly plotted in Nyquist form, using cartesian co-ordinates.

SECTION 4

CIRCUIT DESCRIPTION

The circuit is described in a number of sections corresponding to the various types of sub-unit comprising the complete equipment.
Each section will include a circuit description, component lists and circuit diagram of the sub-unit, together with a table of quiescent voltages and component identification photographs.
The method of obtaining access to the sub-units is described in Section 5.
The following abbreviations and notes are applicable to the component lists.

(1) Notes:—
Blank spaces indicate no change from the preceding line.
In some instances, direct equivalents from other manufacturers may be used.

(2) Abbreviations:—

H.S.	High stability.
W.W.	Wire wound.
M.P.	Metallised paper.
Ce	Ceramic.
M.S.M.	Moulded silvered mica.
T.C.C.	Telegraph Condenser Co.
G.E.C.	General Electric Co.
S.T.C.	Standard Telephones and Cables.

The tables of quiescent voltages are typical values given as a guide to servicing. The most satisfactory method of checking them is to use an extension lead with nine-way micrometer plug at one end and socket at the other. They are measured with respect to earth, with no input signals and the range selector to PRIME.

4.1. SUB-UNIT 1

Sub-unit 1 is the reference amplifier and occurs four times, once in each phase of the reference signal. It is a negative feedback amplifier, of approximately unity gain, operating as a broad band impedance transformer with a high signal current output.
The reference signal from the cathode follower in sub-unit 9 is capacitor-coupled to the signal input pin (B1) on plug 1, 2, 3 or 4. This is connected through the grid stopper R3 into the grid of V1A, the first amplifying valve. Output from the anode of V1A is divided down in R5 and R6 and coupled through grid stopper R7 to the grid of V1B, the second amplifying valve. The output from V1B is divided down in R10 and R11 and coupled through the grid stopper R12 into the grid of V2, the output cathode follower. 100% negative feedback is obtained by directly coupling the cathodes of V1A and V2. The grid of V1A is returned through R1 to a negative potential adjustable by RV1. The cathode of V1B is referred to earth potential through pin (A3) on the input plug. C1 and C3 are provided to correct phase shifts at the higher operating frequencies, and C2, R9 prevents excessive phase shifts and consequent oscillation at frequencies above the maximum operating frequency.

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	—
		B5	Signal Output

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V1	1	100 V	250 V
	6	105 V	250 V
	7	—1·2 V	2·5 V
Junction RV1 and R2		—1 V	2·5 V

Table 1.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R1	3M	1	Painton	73 H.S.	¼	N22128
R2	220k	1			¼	223698
R3	100	10	Erie	9 Carbon	¼	226313
R4	220k	1	Painton	73 H.S.	¼	223698
R5	560k	1			¼	223708
R6	560k	1			¼	223708
R7	100	10	Erie	9 Carbon	¼	226313
R8	270k	1	Painton	73 H.S.	¼	223700
R9	1000	10	Erie	9 Carbon	¼	226325
R10	1·6M	1	Painton	73 H.S.	¼	223719
R11	1M	1			¼	223714
R12	100	10	Erie	9 Carbon	¼	226313
R13	220	10			¼	226317
R14	22	10			¼	226305
R15	5100	1	Painton	P406 W.W.	3	238266
R16	750	1	Erie	109 H.S.	½	221022
RV1	5000	10	Colvern	CLR1206/9S W.W.	½	256412

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C1	10	10	Erie	P100K Ce	500	N20078
C2	68	10	T.C.C.	CSM20N M.S.M.	350	N20114
C3	18	10	Erie	P100L Ce	500	N20120

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V1	12AX7	Double Triode	S.T.C.	315805
V2	A2134	Pentode	G.E.C.	313211
PL1–4	MP9	Plug micrometer 9-way	McMurdo	

NOTES
1. ALL CAPACITOR VALUES GIVEN IN MICRO-FARADS UNLESS OTHERWISE STATED.

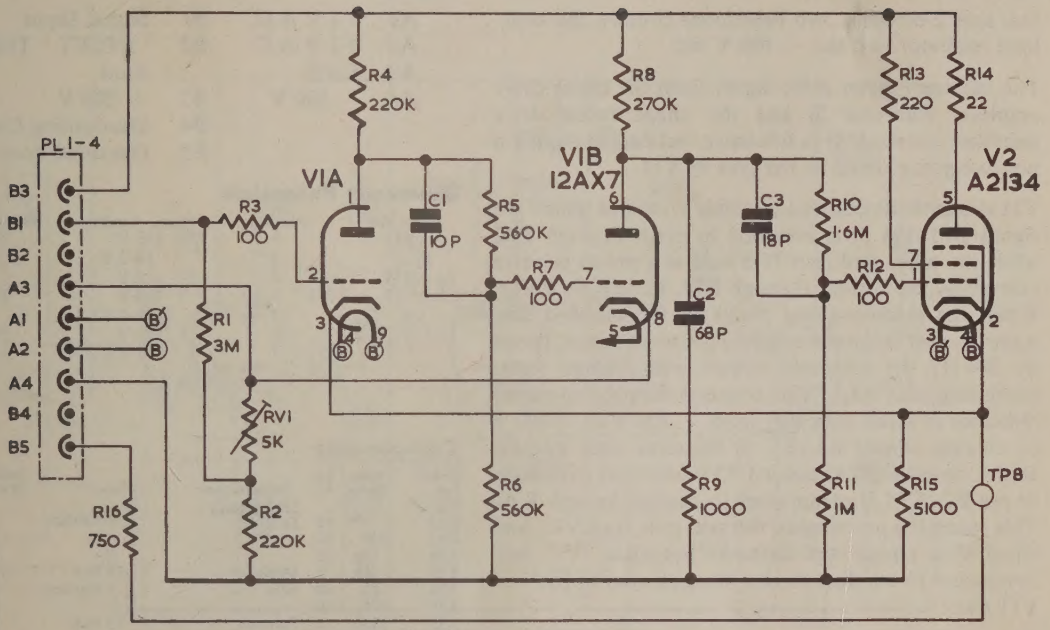


FIG. 3

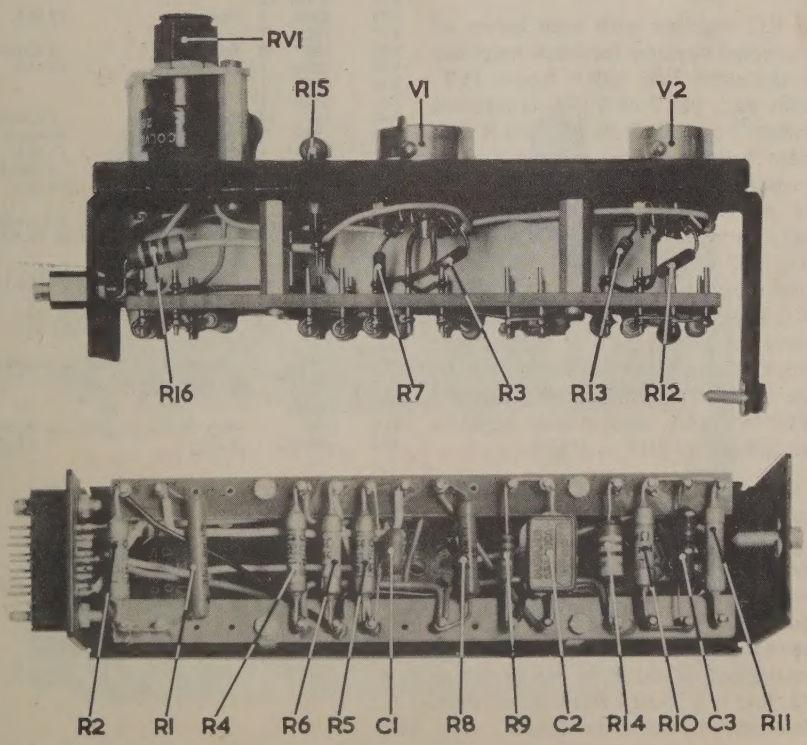


Plate 1: Sub-Unit 1

4.2. SUB-UNIT 2

Sub-unit 2 contains two functional circuits, the overload indicator and the — 100 V rail.

The balanced meter drive signal from the meter drive amplifier (sub-unit 3) and the image meter drive amplifier (sub-unit 4) is full-wave rectified to supply a positive-going signal to the grid of V11.

V11 is a cathode coupled bi-stable circuit in which the signal grid (pin 2) is returned to earth through R22 while the other grid (pin 7) is held at a preset positive voltage by the current through R24, R28, R29, RV11. When the positive-going peaks of the rectified sine waves exceed the predetermined overload signal, preset by RV11, the bi-stable circuit will change state, energising relay RL1. This connects the neon overload indicator in series with R21 from + 200 V to — 100 V by closing contact RL1B. At the same time, contact RL1A opens and capacitor C95 (connected externally to pin B2 of PL5) commences to charge through R30. This raises the potential of the grid (pin 2) of V12, and when this passes the cathode potential, V12 will commence to conduct so that the potential of pin 7 of V11 rises.

The bi-stable circuit V11 will then reset and RL1 will open. If the overload has not been cleared, the sequence will immediately repeat. The resetting time constant of the circuit is approximately two seconds.

The other half of V12 together with both halves of V13 form a D.C. coupled negative feedback amplifier which establishes the earth line 100 V above H.T. negative. The input grid, pin 7 of V13B, is referred to a potential determined by R35, R36, R37 and RV12, the variable element being provided so that precise adjustment of the potential may be achieved. This grid is decoupled against hum and noise by C94 connected externally to pin B4 of PL5. The anode potential of V13B is D.C. coupled through the divider chain R40, R41 into the grid of V13A, and the anode potential of V13A is D.C. coupled through the divider chain R46, R47 into the grid (pin 7) of the cathode follower V12. Both cathodes of V13 and the cathode, pin 8, of V12 are coupled together giving positive feedback from V12 to V13A, and overall negative feedback from the cathode of V12 to V13B.

Any variation of current into or out of the earth line will result in a tendency to change the potential from earth to H.T. negative. This change will provide an error signal between the grid and cathode of V13B, which will be amplified and will control the current of V12 to compensate for the intial change. Thus a stable low impedance earth line is developed. C11 and 13 are to compensate for phase lags in the interstage couplings and C12, R45 is a phase correction network to prevent high-frequency parasitic oscillation.

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	'RESET' Time Constant
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	Decoupling Capacitor
		B5	Overload neon

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V11	1	193 V	250 V
	3	18·3 V	25 V
V12	7	—2 V	2·5 V
V13	1	100 V	250 V
	2	—1·1 V	2·5 V
	6	100 V	250 V
	7	—1·1 V	2·5 V

Table 2.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R21			Not fitted			
R22	1M	10	Erie	9 Carbon	¼	226361
R23	100	10			¼	226313
R24	10k	10		8	¼	226537
R25	10k	5	Welwyn	F5 M F.	3	235637
R26	22	10	Erie	9 Carbon	¼	226305
R27	100	10			¼	226313
R28	180k	1	Painton	73 H.S.	¼	223696
R29	120k	1			¼	223692
R30	2·2M	10	Erie	9 Carbon	¼	226365
R31	100	10			¼	226313
R32	22	10			¼	226305
R33	22	10			¼	226305
R34	100	10			¼	226313
R35	4·7M	10			¼	226369
R36	220k	1	Painton	73 H.S.	¼	223698
R37	100k	1			¼	223690
R38	100	10	Erie	9 Carbon	¼	226313
R39	220k	1	Painton	73 H.S.	¼	223698
R40	560k	1			¼	223708
R41	560k	1			¼	223708
R42	100	10	Erie	9 Carbon	¼	226313
R43	33k	2	Welwyn	Welmet M.F.	1	235385
R44	220k	1	Painton	73 H.S.	¼	223698
R45	1000	10	Erie	9 Carbon	¼	226325
R46	560k	1	Painton	73 H.S.	¼	223708
R47	560k	1			¼	223708
RV11	25k	20	Morganite	LH Carbon	¼	251206
RV12	5000	10	Colvern	CLR1206/9S W.W.	¼	256412

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C11	150	10	T.C.C.	CSM20N M.S.M.	350	N20119
C12	150	10			350	N20119
C13	22	10	Erie	P100L Ce	500	N20121
C14	·25	20	Hunt	AM109 MPI	350	N20237

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V11	12AT7	Double Triode	S.T.C.	315801
V12	12AT7			315801
V13	12AX7			315805
PL5	MP9	Plug Micronector 9-way	McMurdo	
RL1	4193BA	Relay	S.T.C.	

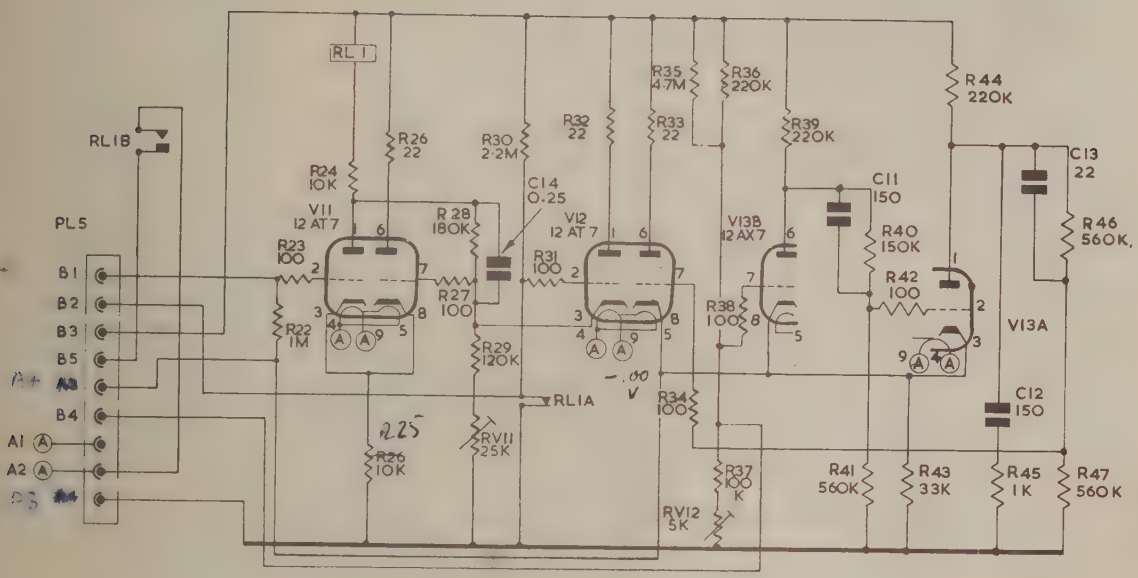
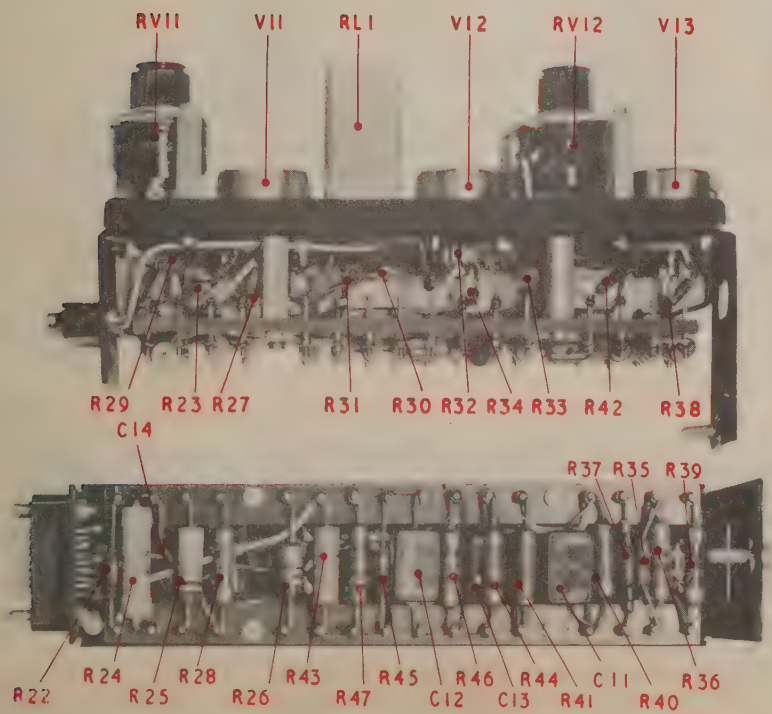

RL1
RL1B
PL5
B1
B2
B3
B5
B4
A1
A2
R24 10K
R26 22
R30 2·2M
R32 22
R33 22
R35 4·7M
R36 220K
R39 220K
R44 220K
C13 22
C11 150
R40 150K
R42 100
R46 560K,
V13A
V11 12 AT7
R23 100
R22 1M
R28 180K
C14 0·25
R27 100
R29 120K
V12 12 AT7
R31 100
V13B 12 AX7
R38 100
RL1A
R34 100
C12 150
R26 10K
RV11 25K
R37 100 K
RV12 5K
R41 560K
R43 33K
R45 1K
R47 560K

FIG. 4.


RV11
V11
RL1
V12
RV12
V13
R29
R23
R27
R31
R30
R32
R34
R33
R42
R38
C14
R37
R35
R39
R22
R24
R25
R28
R26
R43
R47
R45
C12
R46
C13
R44
R41
C11
R40
R36

4.3. SUB-UNIT 3

This sub-unit contains a unity gain negative feedback amplifier consisting of three valves.

V21A is one-half of a double-triode type 12AX7 which receives its input through the grid stopper R63. The output of V21A is D.C. coupled through the divider chain R65, R66, to the grid of V21B, the second amplifying stage.

The output from V21B is D.C. coupled through R70 and R71 into the grid of the cathode follower V22 an A2134. Negative feedback is taken from the cathode of V22 to the cathode of V21A.

RV22 adjusts the voltage to which the grid of V21A is returned and sets up the D.C. conditions of the amplifier. RV21 varies the low-frequency transmission characteristics of the amplifier and is used to balance the low-frequency phase shifts in the signal and reference channels. C21 and C23 provide H.F. coupling between stages to reduce phase errors at the highest frequencies of operation.

C22, R69 is a phase-shaping network designed to prevent H.F. instability.

MR1 is a half-wave rectifier which feeds signals to the overload detector (Sub-unit 2).

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	Rectified Signal Output
		B5	Signal Output

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V21	1	100 V	250 V
	6	120 V	250 V
	7	—1·5 V	2·5 V
V22	1	—17 V	25 V
Junction RV21 and RV22		—1·3 V	2·5 V

Table 3.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R61	1·5M	2	Painton	73 H.S.	¼	223918
R62	220k	1			¼	223698
R63	100	10	Erie	9 Carbon	¼	226313
R64	270k	1	Painton	73 H.S.	¼	223700
R65	560k	1			¼	223708
R66	560k	1			¼	223708
R67	100	10	Erie	9 Carbon	¼	226313
R68	270k	1	Painton	73 H.S.	¼	223700
R69	1000	10	Erie	9 Carbon	¼	226325
R70	1·6M	1	Painton	73 H.S.	¼	223719
R71	1M	1			¼	223714
R72	100	10	Erie	9 Carbon	¼	226313
R73	220	10			¼	226317
R74	22	10			¼	226305
R75	3600	1	Painton	P306 W.W.	3	238262
RV21	2·5M	20	Morganite	LH Carbon	¼	251212
RV22	5000	10	Colvern	CLR1206/9S W.W.	¼	256412

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C21	33	10	Erie	N150L Ce	500	N20077
C22	68	10	T.C.C.	CSM20N M.S.M.	350	N20114
C23	6·8	·25pf	Erie	P100K Ce	500	201011

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V21	12AX7	Double Triode	S.T.C.	315805
V22	A2134	Pentode	G.E.C.	313211
MR1	GEX35	Germanium Diode	G.E.C.	
PL6	MP9	Plug Micronector 9-way	McMurdo	

NOTES
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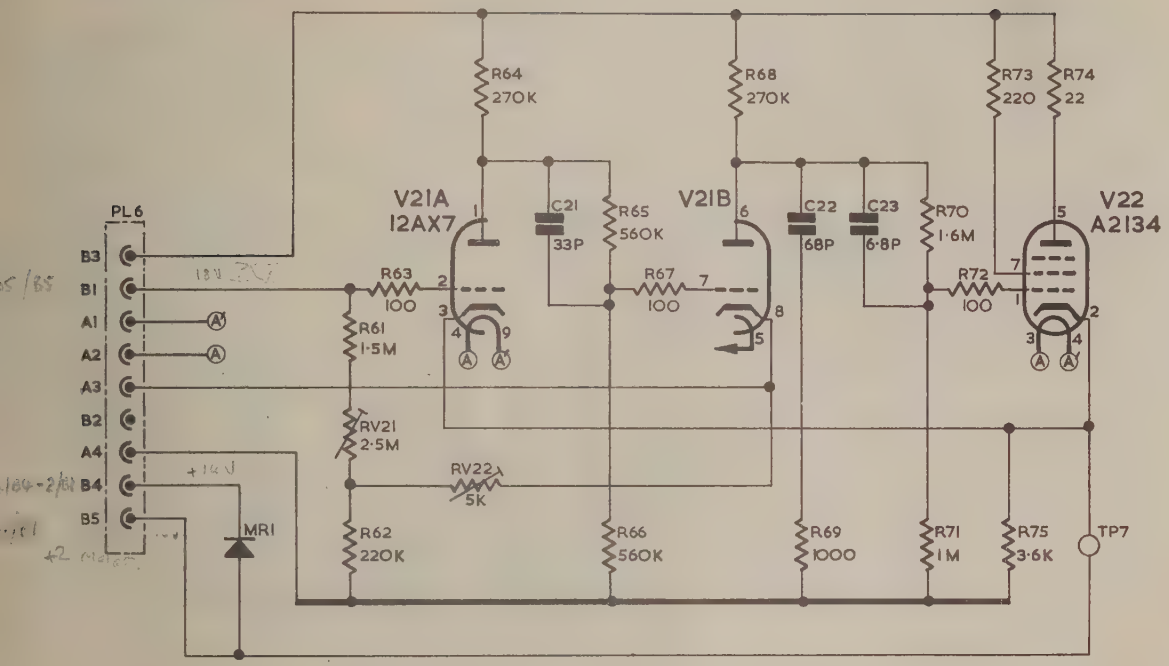


FIG. 5

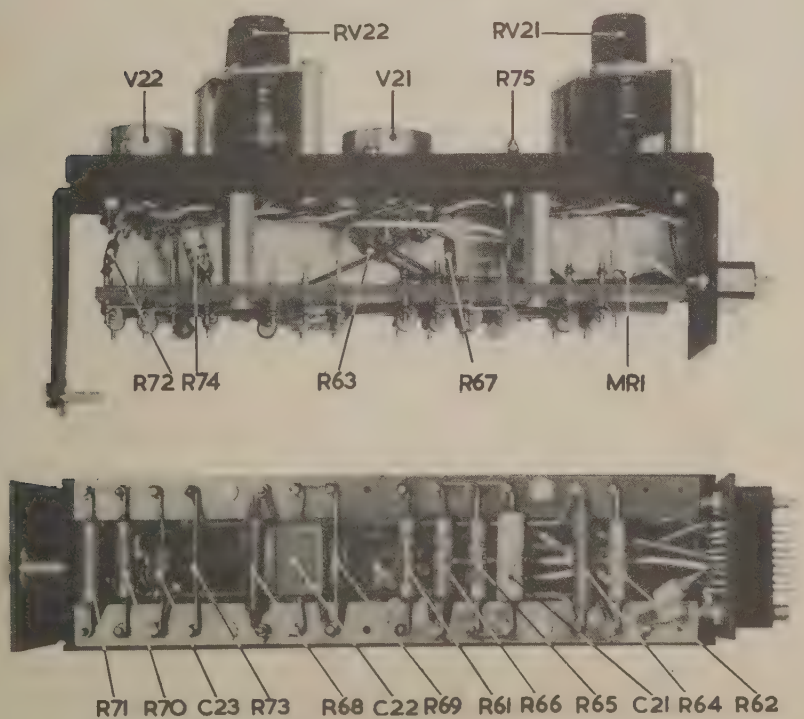


Plate 3: Sub-Unit 3

4.4. SUB-UNIT 4

Sub-unit 4 contains a unity gain image amplifier which together with sub-unit 3 provides balanced signal drive to the thermocouple meters. The input and output signals are added in R81, R84 to provide a difference signal which is fed into the input grid (pin 7) of V31.

V31 is a cathode coupled amplifier, the first half acting as a cathode follower coupling signal into the cathode of the second half. Amplified signal from the output of V31 is D.C. coupled through the divider chain R90, R92, into the grid (pin 7) of V32. The amplified output of V32 is D.C. coupled into the grid of the cathode follower V33, through the divider chain R94, R95.

Negative feedback signal from the output is balanced against the input signal in the see-saw resistors R81, R84. C31, C32, C34 and C35 provide H.F. coupling between stages to reduce phase errors at the highest frequencies of operation. C33, R89 is a phase-shaping network designed to prevent H.F. instability. The second half of V32 is connected as a diode and feeds signal to the overload detector (Sub-unit 2).

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	Rectified Signal Output
		B5	Signal Output

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V31	1	100 V	250 V
	2	1 V	2·5 V
	3	1·7 V	2·5 V
V32	6	122 V	250 V
	7	−1·5 V	2·5 V
V33	1	−15 V	25 V

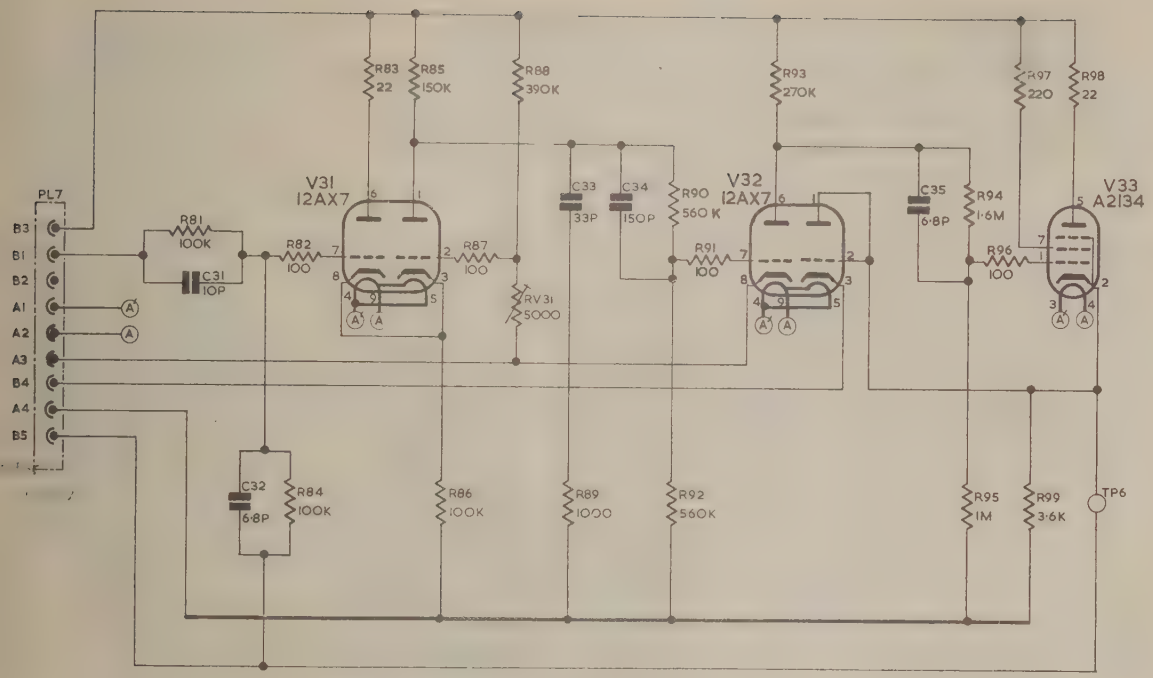
Table 4.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R81	100k	1	Painton	73 H.S.	¼	223690
R82	100	10	Erie	9 Carbon	¼	226313
R83	22	10			¼	226305
R84	100k	1		109 H.S.	¼	221073
R85	150k	1	Painton	73	¼	223694
R86	100k	1			¼	223690
R87	100	10	Erie	9 Carbon	¼	226313
R88	390k	1	Painton	73 H.S.	¼	223704
R89	1000	10	Erie	9 Carbon	¼	226325
R90	560k	1	Painton	73 H.S.	¼	223708
R91	100	10	Erie	9 Carbon	¼	226313
R92	560k	1	Painton	73 H.S.	¼	223708
R93	270k	1			¼	223700
R94	1·6M	1			¼	223719
R95	1M	1			¼	223714
R96	100	10	Erie	9 Carbon	¼	226313
R97	220	10			¼	226317
R98	22	10			¼	226305
R99	3600	1	Painton	P306 W.W.	3	238262
RV31	5000	10	Colvern	CL1206/9S W.W.	¼	256412

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C31	10	10	Erie	P100K Ce	500	N20078
C32	6·8	·25pf			500	201011
C33	33	10		N150L	500	N20077
C34	150	10	T.C.C.	CSM20N M.S.M.	350	N20119
C35	6·8	·25pf	Erie	P100K Ce	500	201011

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V31	12AX7	Double Triode	S.T.C.	315805
V32	12AX7			315805
V33	A2134	Pentode	G.E.C.	313211
PL7	MP9	Plug Micronector 9-way	McMurdo	



NOTES

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FIG. 6

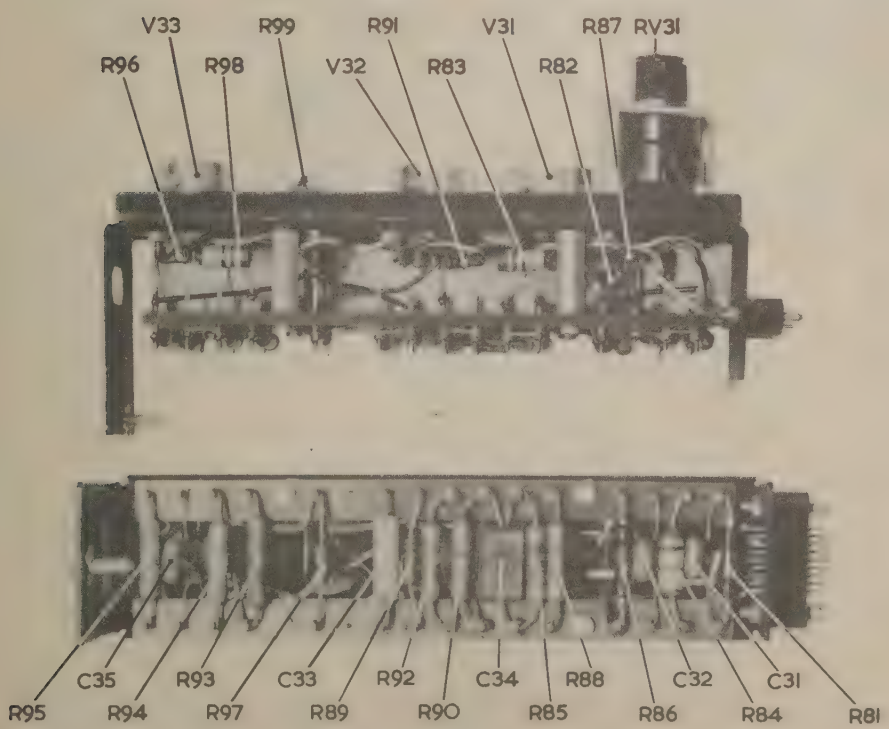

Plate 4: Sub-Unit 4

4.5. SUB-UNIT 5

Sub-unit 5 is the main signal amplifier and has a gain of about 25. It is a negative feedback amplifier, having two stages of gain in cascade followed by a cathode follower. Negative feedback is taken from the output cathode to the cathode of the first amplifier. Input signal from pin B1 of plug PL8 is connected through the grid stopper R102 into the grid of the first amplifier V41A, one-half of a 12AX7. This grid is returned to earth through the grid leak R101. Cathode current through R105, RV41 is used to give the required bias and RV41 is adjusted for zero D.C. at test point 5. The output of V41A is D.C. coupled into the grid of the second amplifier V41B through the divide down network comprising R108, R109.

The output from the second amplifier is D.C. coupled through the divide down network R112, R113 into the grid of the cathode follower V42, one-half of a 12AX7. (The second half of this valve is not used.)

R117 is the cathode load, and negative feedback is taken from the output point to the cathode of V41A through the negative feedback attenuator comprising R115, RV42, R103. RV42 is provided to accurately preset the overall gain of the amplifier. R107 forms the D.C. current path for V41A current. C42 and C43 are H.F. coupling capacitors provided to minimise phase shifts at the higher frequencies of operation and C41, R104 form a phase-shaping network to prevent H.F. instability.

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	—
		B5	Signal Output

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V41	1	100 V	250 V
	3	1 V	2·5 V
	6	98 V	100 V
	7	—1 V	2·5 V
V42	7	—2 V	2·5 V

Table 5.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R101	2·2M	1	Dubilier	417 H.S.	½	N22129
R102	100	10	Erie	9 Carbon	¼	226313
R103	1800	1	Painton	73 H.S.	½	223648
R104	10k	10	Erie	9 Carbon	¼	226337
R105	1800	2	Painton	73 H.S.	½	223848
R106	220k	1			½	223698
R107	330k	10	Erie	9 Carbon	¼	226355
R108	560k	1	Painton	73 H.S.	½	223708
R109	560k	1			½	223708
R110	100	10	Erie	9 Carbon	¼	226313
R111	220k	1	Painton	73 H.S.	½	223698
R112	560k	1			½	223708
R113	560k	1			½	223708
R114	100	10	Erie	9 Carbon	¼	226313
R115	39k	1	Painton	73 H.S.	½	223679
R116	22	10	Erie	9 Carbon	¼	226305
R117	82k	1	Painton	73 H.S.	½	223688
RV41	2500	10	Colvern	CLR1206/9S W.W.	½	256411
RV42	10k	10	Colvern	CLR1206/9S W.W.	½	256413

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C41	220	10	T.C.C.	CSM20N M.S.M.	350	N20122
C42	150	10			350	N20119
C43	10	10	Erie	P100K Ce	500	N20078

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V41	12AX7	Double Triode	S.T.C.	315805
V42	12AX7			
PL8	MP9	Plug Micronector 9-way McMurdo		

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NOTES
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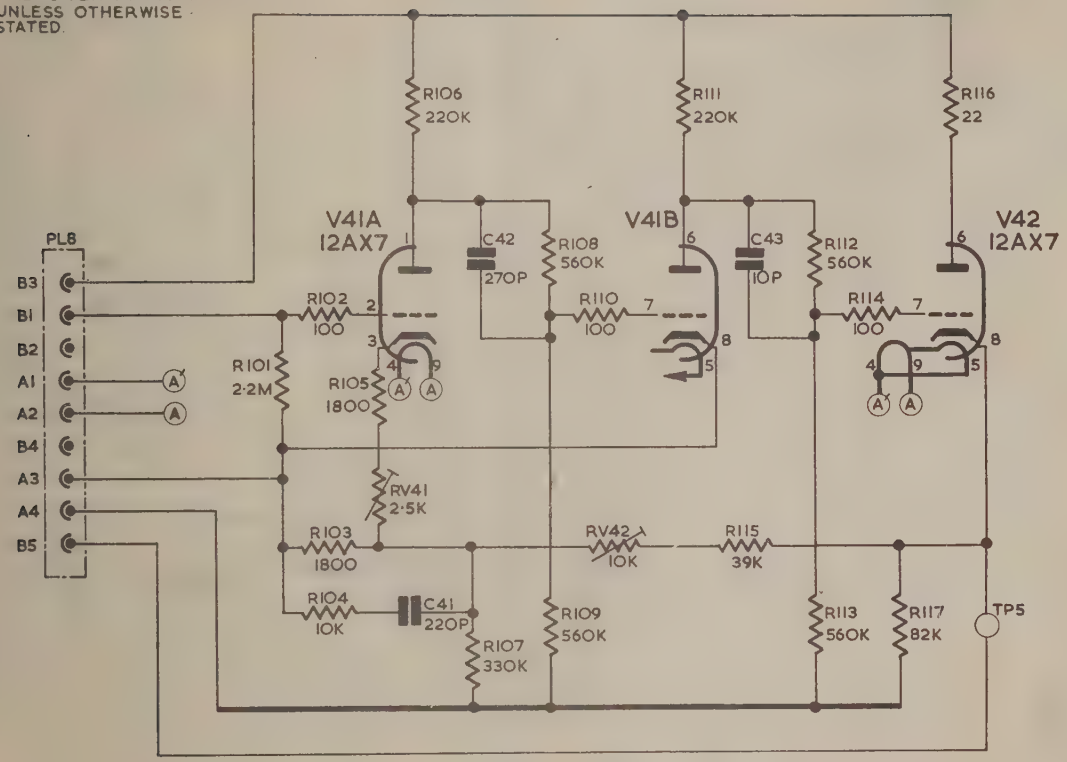


FIG.7

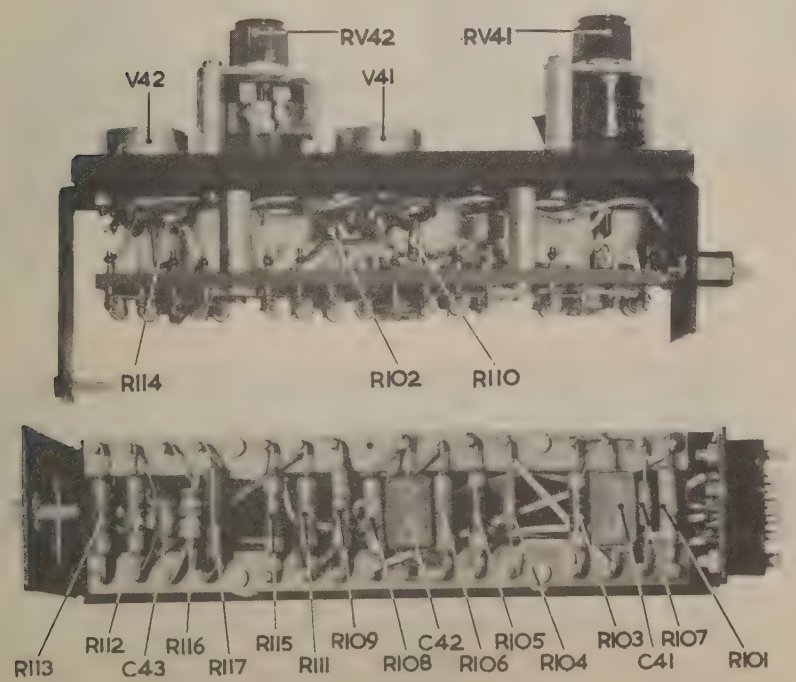


Plate 5: Sub-Unit 5

4.6. SUB-UNIT 6

Sub-unit 6 houses the 180° amplifier and the common mode rejection imaging amplifier.

Input signal from pin B1 of plug PL9 is connected through the grid stopper R121 directly into the grid of the triode connected low-noise pentode input amplifier V51. Cathode current bias for this stage is developed across R126 and RV51 which adjust D.C. levels to give zero quiescent output at test point 4.

The output of V51 is directly coupled to the grid of V52A, the second amplifier through the divide down chain R127, R128. The output from V52A is divided down in R131, R132 into the grid of the cathode follower V52B. Negative feedback is taken from the cathode of V52B through the gain determining negative feedback attenuator R134, R122, R123 to the cathode of V51.

C51 and C52 are provided to give phase correction at the higher operational frequencies.

The output from the cathode follower is connected through R137 into the input grid, pin 2, of V53. This stage is an amplifier and cathode follower employing negative feedback from the output to the input grid through R140, R141. The object of this unity gain stage is to reverse the 180° phase before adding it to the 0° phase. The 180° adding resistors are R148, and RV52 which is adjusted for maximum common mode rejection. C53 and C54 are provided to give phase correction at the higher operational frequencies.

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	—
		B5	Signal Output

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V51	1 & 6	100 V	250 V
	3 & 8	2·2 V	2·5 V
V52	1	89 V	100 V
	2	—0·9 V	2·5 V
	8	—4·3 V	10 V
V53	1	99 V	250 V
	2	—3 V	10 V
	7	—2 V	2·5 V

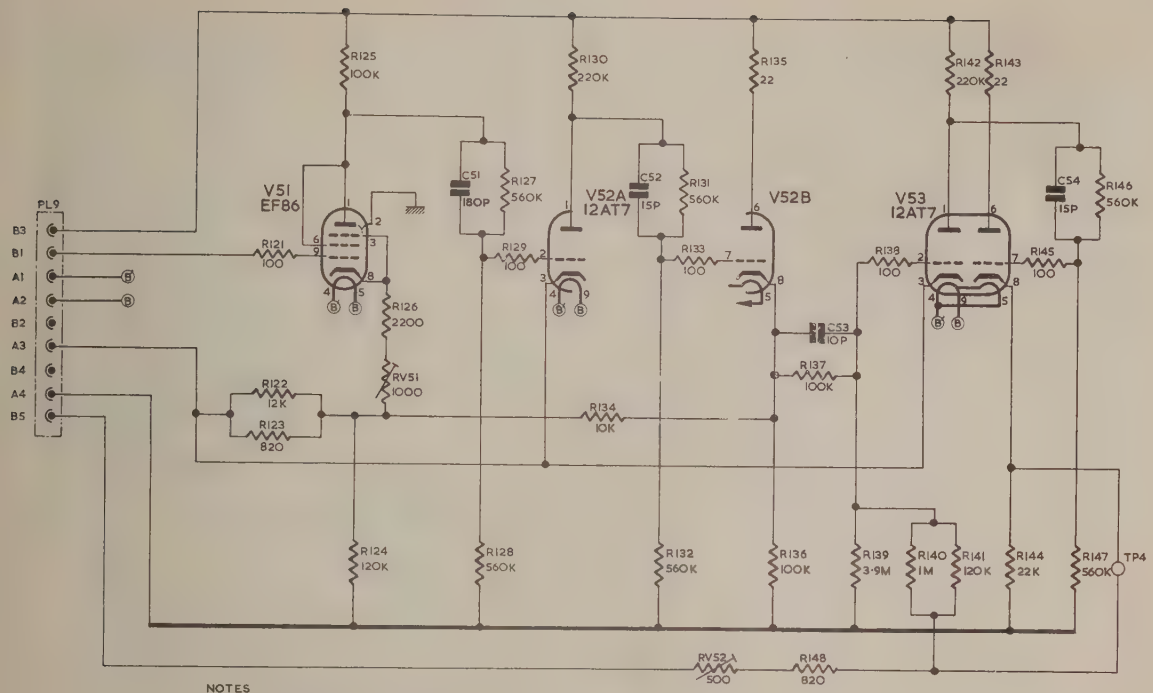
Table 6.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R121	100	10	Erie	9 Carbon	¼	226313
R122	12k	10			¼	226338
R123	820	1	Painton	73 H.S.	½	223640
R124	120k	10	Erie	9 Carbon	¼	226350
R125	100k	1		109 H.S.	½	221073
R126	2200	1	Painton	73	½	223650
R127	560k	1			½	223708
R128	560k	1			½	223708
R129	100	10	Erie	9 Carbon	¼	226313
R130	220k	1		109 H.S.	½	221081
R131	560k	1	Painton	73	½	223708
R132	560k	1			½	223708
R133	100	10	Erie	9 Carbon	¼	226313
R134	10k	1	Painton	73 H.S.	½	223666
R135	22	10	Erie	9 Carbon	¼	226305
R136	100k	2	Welwyn	Welmet M.F.	1	235397
R137	100k	1	Painton	73 H.S.	½	223690
R138	100	10	Erie	9 Carbon	¼	226313
R139	3·9M	10			¼	226368
R140	1M	10			¼	226361
R141	120k	1	Painton	73 H.S.	½	223692
R142	220k	1	Erie	109	½	221081
R143	22	10		9 Carbon	¼	226305
R144	22k	2	Welwyn	Welmet M.F.	1	235381
R145	100	10	Erie	9 Carbon	¼	226313
R146	560k	1	Painton	73 H.S.	½	223708
R147	560k	1			½	223708
R148	820	1	Erie	109	½	221023
RV51	1000	10	Colvern	CLR1206/9S W.W.	½	256410
RV52	500	10			½	256409

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C51	180	10	T.C.C.	CSM20N M.S.M.	350	N20119
C52	15	10	Erie	P100K Ce	500	N20078
C53	10	10			500	N20078
C54	15	10			500	N20078

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V51	EF86	Pentode	Mullard	
V52	12AT7	Double Triode	S.T.C.	315805
V53	12AT7			515807
PL9	MP9	Plug Micronector 9-way McMurdo		



NOTES

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FIG. 8

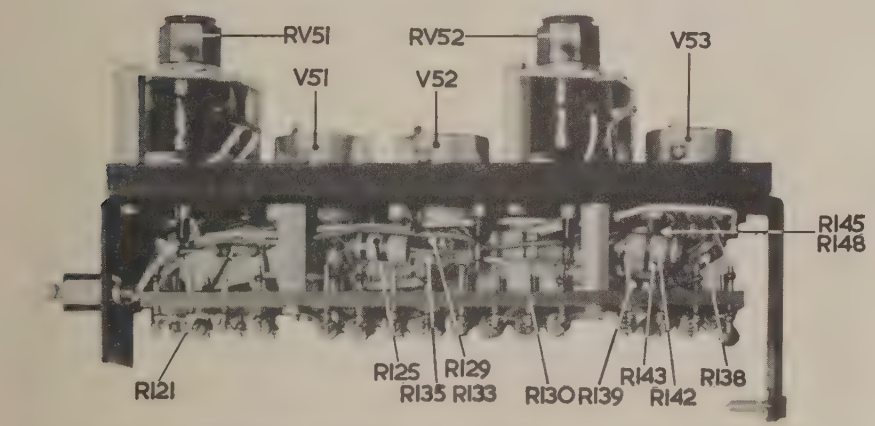


Plate 6: Sub-Unit 6

4.7. SUB-UNIT 7

Sub-unit 7 is the 0° amplifier and is almost identical to the 180° amplifier excluding the common mode rejection inverter.

Input signal from B1 on PL10 is coupled through R151 into the grid of V61. R156 and RV61 are the cathode bias resistors and RV61 is adjusted for zero quiescent volts at the cathode of V26B (TP3). Output from V61 is D.C. coupled through R157, R158 into the grid of V62A, the second stage of gain. Output from V62A is coupled through R161, R162 into the grid of the cathode follower V62B. Negative feedback is taken from the cathode of V62B through the gain determining negative feedback network R164, R152, R153 to the cathode of V61. The output signal is connected to the output through the summing resistor R167. C61, C62 and C63 are provided to correct the phase shift at higher operational frequencies and eliminate parasitic oscillation.

Plug connections are as follows:—

A1	6·3 V A.C.	B1	Signal Input
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	—
		B5	Signal Output

Quiescent Voltages

Valve No.	Pin No.	Meter Reading	Meter Range
V61	1 & 6	98 V	250 V
	3 & 8	2 V	2·5 V
V62	1	97 V	250 V
	2	—1·7 V	2·5 V
	7	—1·8 V	2·5 V

Table 7.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R151	100	10	Erie	9 Carbon	¼	226313
R152	12k	10			¼	226338
R153	820	1	Painton	73 H.S.	½	223640
R154	100k	1			½	223690
R155	120k	10	Erie	9 Carbon	¼	226350
R156	1800	2	Painton	73 H.S.	½	223848
R157	560k	1			½	223708
R158	560k	1			½	223708
R159	100	10	Erie	9 Carbon	¼	226313
R160	220k	1	Painton	73 H.S.	½	223698
R161	560k	1			½	223708
R162	560k	1			½	223708
R163	100	10	Erie	9 Carbon	¼	226313
R164	10k	1	Painton	73 H.S.	½	223666
R165	22	10	Erie	9 Carbon	¼	226305
R166	22k	2	Welwyn	Welmet M.F.	1	235381
R167	1000	1	Painton	73 H.S.	½	223642
RV61	1000	10	Colvern	CLR1206/9S W.W.	½	256410

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C61	100	10	T.C.C.	CSM20N M.S.M.	350	N20123
C62	15	10	Erie	P100K Ce	500	N20078
C63	22	10		P100L	500	N20121

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V61	EF86	Pentode	Mullard	
V62	12AT7	Double Triode	S.T.C.	315801
PL10	MP9	Plug Micronector 9-way	McMurdo	

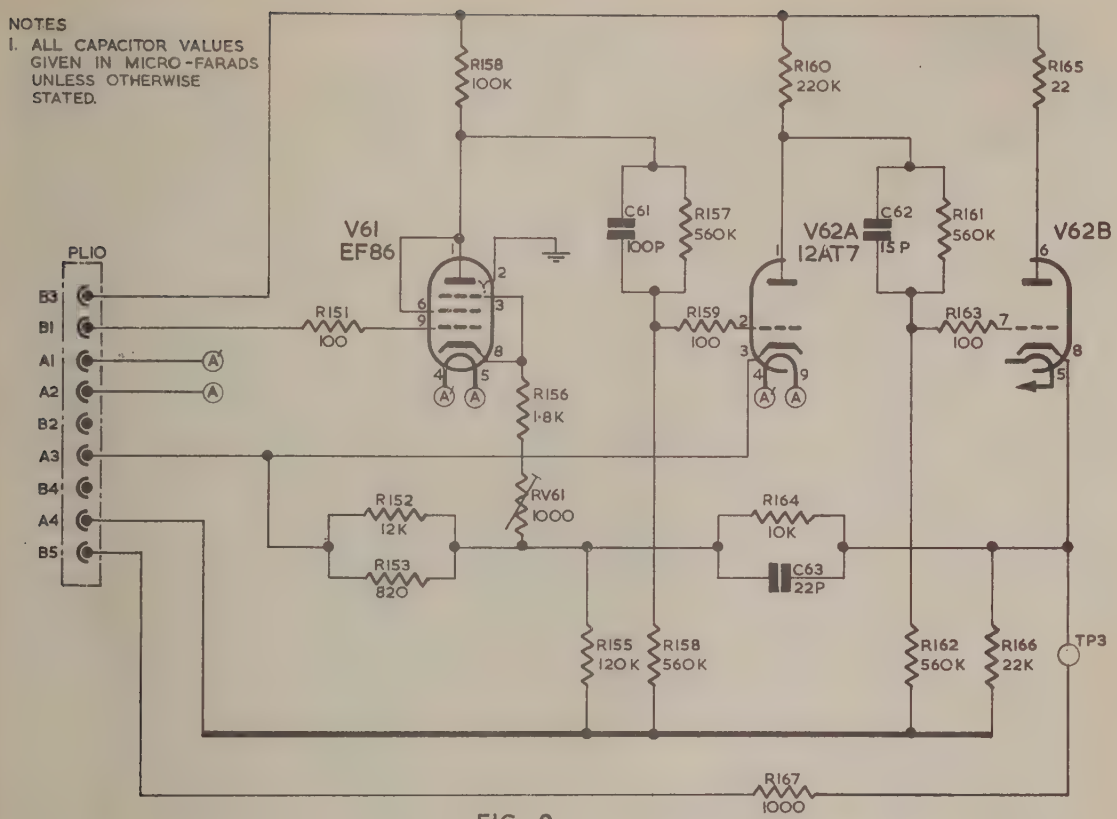
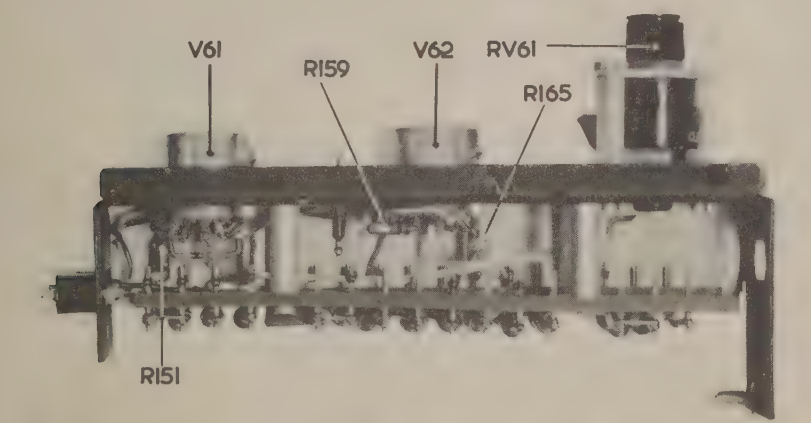


FIG. 9



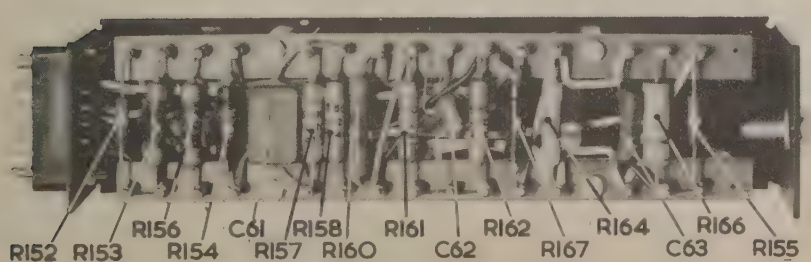


Plate 7: Sub-Unit 7

4.8. SUB-UNIT 8

Sub-unit 8 is the 0° and 180° input cathode followers and attenuators. Except for the balance–unbalance switch SW73, both channels are identical, and only one will be described. It should be noted that SW71 and SW72 are ganged so that minimum sensitivity is fully clockwise on SW71 and fully anti-clockwise on SW72.

Considering the 180° channel, the signal enters the equipment in the coaxial socket SK71 and is coupled through the 2 μFd capacitor C71 on to the input attenuator, controlled by SW71/1R. There is no attenuation on the first six positions of this switch. The next two positions give attenuations of approximately 10 db per step in two simple ladder attenuators having impedances of 10 MΩ. The ninth position is the PRIME position which is provided so that C71 may be rapidly charged when the signal to be measured is superimposed on a large DC voltage. C72, C73 and C74 are provided to correct phase shifts at the higher operating frequencies.

The output from the high-impedance input attenuator is connected through the grid stopper R175 to the grid of the input cathode follower V71, a triode connected low noise pentode, type 6BS7. The high-impedance attenuator is returned to a negative potential at the wiper of RV71 which is adjusted to give zero quiescent potential at the cathode of V71 (TP1).

The cathode follower drives the low-impedance ladder attenuator which alters the signal transmission on the first six positions and remains constant for the remaining two. The output signal socket SKT72 is connected to this attenuator through SW72/1R which selects the required transmission and earths the output in the PRIME position.

The overall circuit may thus be considered as a broad band impedance transformer having various transmissions corresponding to input sensitivities for full-scale deflection of 50 mV, 150 mV, 500 mV, 1·5 V, 5 V, 15 V, 50 V and 150 V.

Plug connections are as follows:—

A1	6·3 V A.C.	B1	—
A2	6·3 V A.C.	B2	—
A3	Earth	B3	+ 200 V
A4	— 100 V	B4	—
		B5	—

180° signal input is on the coaxial socket SKT71 and output on SKT72.

0° signal input is on the coaxial socket SKT73 and output on SKT74.

Quiescent Potentials

Valve No.	Pin No.	Meter Reading	Meter Range
V71	T.C.	—9 V	10 V
V72	T.C.	—9 V	10 V

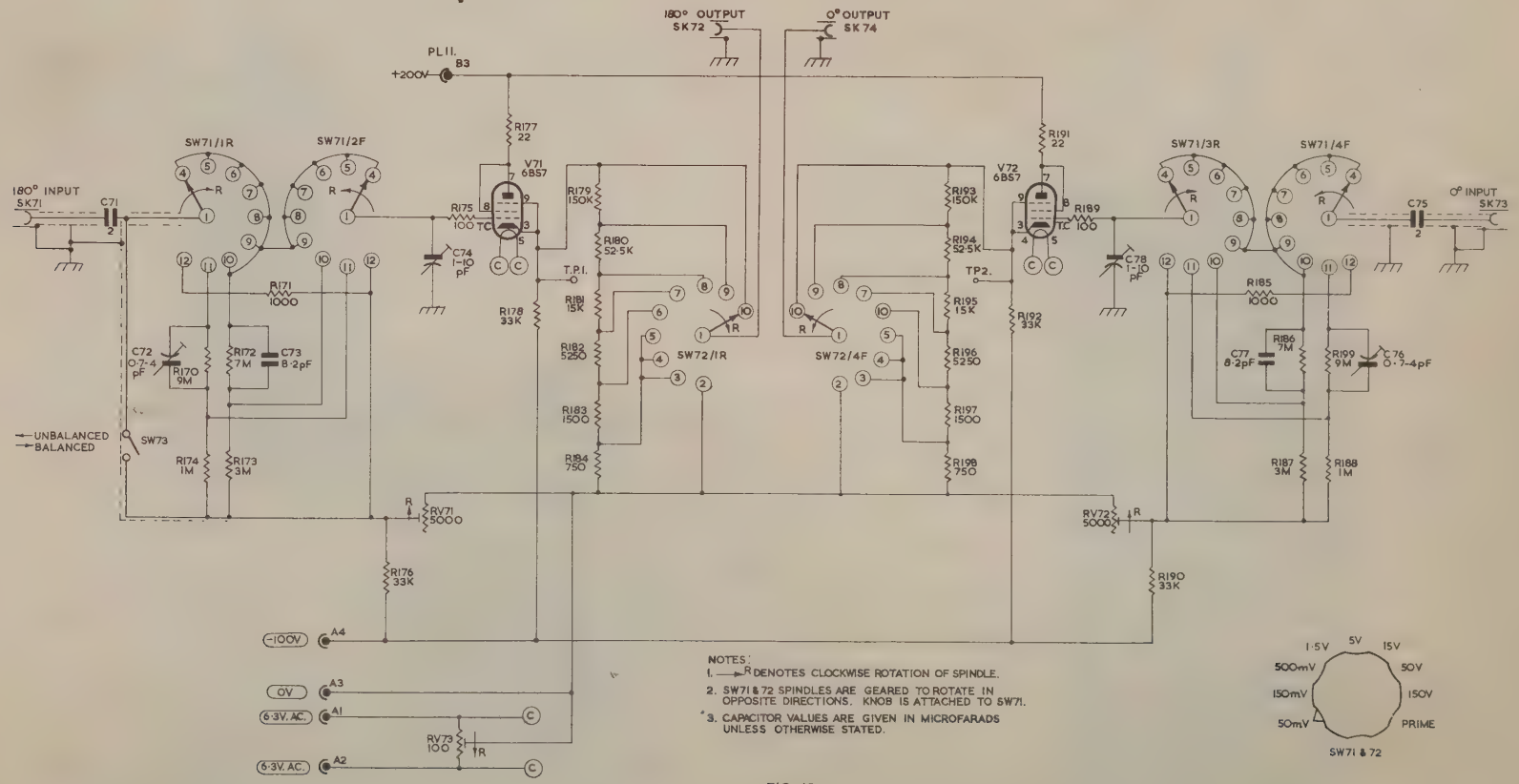
Table 8.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R170	9M	1	Labgear	HS3 H.S.	½	N22352
R171	1000	10	Erie	9 Carbon	¼	226325
R172	7M	1	Labgear	HS3 H.S.	½	N22130
R173	3M	1	Labgear	HS3 H.S.	½	N22128
R174	1M	1	Painton	73 H.S.	½	223714
R175	100	10	Erie	9 Carbon	¼	226313
R176	33k	10			¼	226343
R177	22	10			¼	226305
R178	33k	1	Painton	73 H.S.	½	223678
R179	150k	1		73	½	223694
R180	52·5k	1			½	N22132
R181	15k	1			½	223670
R182	5250	1			½	N22592
R183	1500	1			½	223646
R184	750	1			½	223639
R185	1000	10	Erie	9 Carbon	¼	226325
R186	7M	1	Labgear	HS3 H.S.	½	N22130
R187	3M	1	Labgear	HS3 H.S.	½	N22128
R188	1M	1	Painton	73 H.S.	½	223714
R189	100	10	Erie	9 Carbon	¼	226313
R190	33k	10			¼	226343
R191	22	10			¼	226305
R192	33k	2	Painton	73 H.S.	½	223878
R193	150k	1			½	223694
R194	52·5k	1			½	N22132
R195	15k	1			½	223670
R196	5250	1			½	N22295
R197	1500	1			½	223646
R198	750	1			½	223639
R199	9M	1	Labgear	HS3 H.S.	½	N22352
RV71	5000	10	Colvern	CLR1206/9S W.W.	½	256412
RV72	5000	10			½	256412
RV73	100	10			½	256407

Circuit Ref.	Value Pfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C71	2 μF	5	T.C.C.	CP144T Pa	600	N20074
C72	·7/4		Wingrove & Rogers	S50–01/1 P.T.F.E.	1K	243001
C73	8·2	·25pf	Erie	P100K Ce	750	201012
C74	1/10		Wingrove & Rogers	S55–11	1K	N24009
C75	2 μF	5	T.C.C.	CP144T Pa	600	N20074
C76	·7/4		Wingrove & Rogers	S50–01/1 P.T.F.E.	1K	243001
C77	8·2	·25pf	Erie	P100K Ce	750	201012
C78	1/10		Wingrove & Rogers	S55–11	1K	N24009

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V71	6BS7	Low-noise Pentode	S.T.C.	
V72	6BS7			
SW71		Switch Wafer		261040
SW72				261041
SW73		Switch Toggle	Bonella	
SK71	UG447/U	Socket Coaxial	Transradio	
SK72				
SK73				
SK74				
PL11	MP9	Plug micronector 9-way	McMurdo	



NOTES:
1. → R DENOTES CLOCKWISE ROTATION OF SPINDLE.
2. SW71 & 72 SPINDLES ARE GEARED TO ROTATE IN OPPOSITE DIRECTIONS. KNOB IS ATTACHED TO SW71.
3. CAPACITOR VALUES ARE GIVEN IN MICROFARADS UNLESS OTHERWISE STATED.

FIG. 10

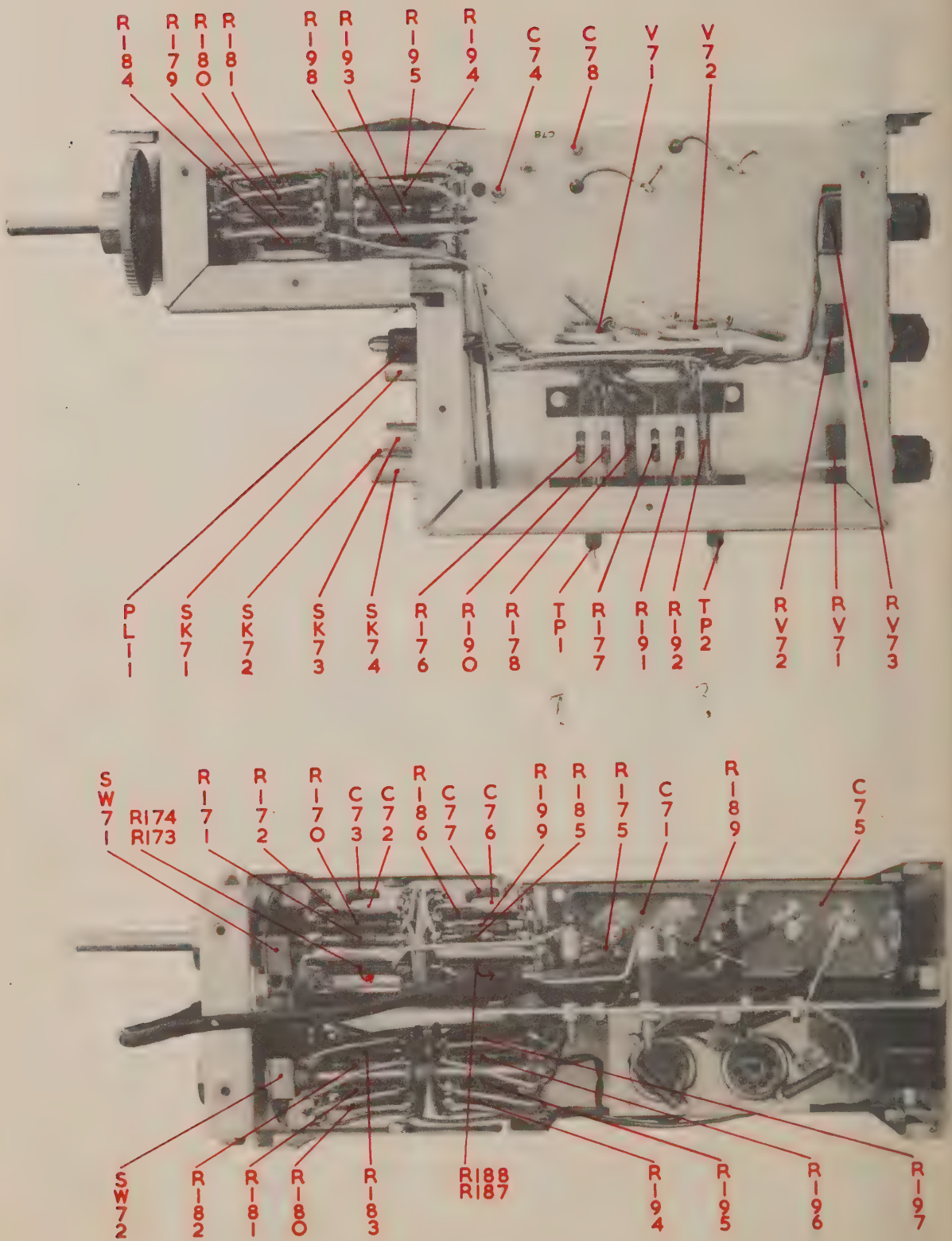


Plate 8: Sub-Unit 8

4.9. SUB-UNIT 9

Sub-unit 9 is built on a printed-circuit board and comprises four identical reference input cathode followers. The four-phase input signal is connected into the unit on four solder pins. Each phase is A.C. coupled into the grid of its respective cathode follower through a 2 μFd capacitor and in each case the grid resistor is 6·2 MΩ. The output is developed across a 220 K cathode load and A.C. coupled through a 4 μFd capacitor to the reference amplifier (sub-unit 1). The object of these cathode followers is to introduce two time constants into each reference channel so that the three time constants of the signal channel may be more easily compensated.

The solder pin connections are:—

1.	— 100V	6.	90° Input
2.	Earth	7.	180° Input
3.	+ 200 V	8.	6·3 V A.C.
4.	270° Input	9.	6·3 V A.C.
5.	0° Input		

The plug connections are:—

A1	180° Output	B1	270° Output
A2	—	B2	—
A3	—	B3	—
A4	90° Output	B4	—
		B5	0° Output

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R201	6·2M	1	Labgear	HS3 H.S.	½	N22133
R202	100	10	Erie	9 Carbon	¼	226313
R203	22	10			¼	226305
R204	220k	10			¼	226353
R205	6·2M	1	Labgear	HS3 H.S.	½	N22133
R206	100	10	Erie	9 Carbon	¼	226313
R207	22	10			¼	226305
R208	220k	10			¼	226353
R209	6·2M	1	Labgear	HS3 H.S.	½	N22133
R210	100	10	Erie	9 Carbon	¼	226313
R211	22	10			¼	226305
R212	220k	10			¼	226353
R213	6·2M	1	Labgear	HS3 H.S.	½	N22133
R214	100	10	Erie	9 Carbon	¼	226313
R215	22	10			¼	226305
R216	220k	10			¼	226353
R217						

Circuit Ref.	Value μFd	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C81	2	5	Static	TC1785 Pa	100	N20150
C82	4	5		TC1786	100	N20151
C83	2	5		TC1785	100	N20150
C84	4	5		TC1786	100	N20151
C85	2	5		TC1785	100	N20150
C86	4	5		TC1786	100	N20151
C87	2	5		TC1785	100	N20150
C88	4	5		TC1786	100	N20151

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
V81	12AX7	Double Triode	S.T.C.	315805
V82	12AX7			315805
PL13	MP9	Plug Micronector 9-way	McMurdo	

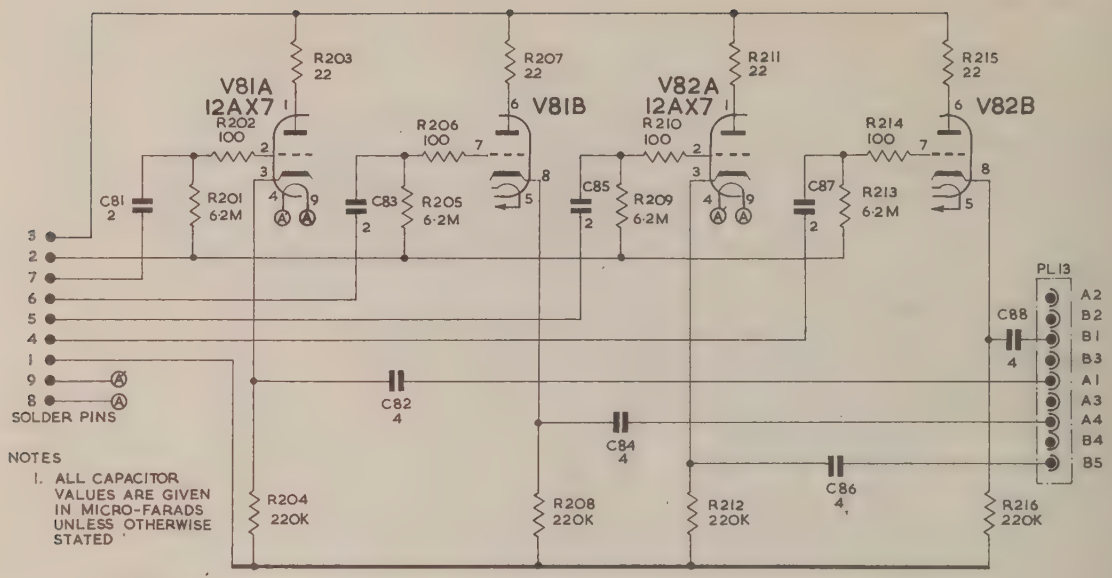


FIG. 11

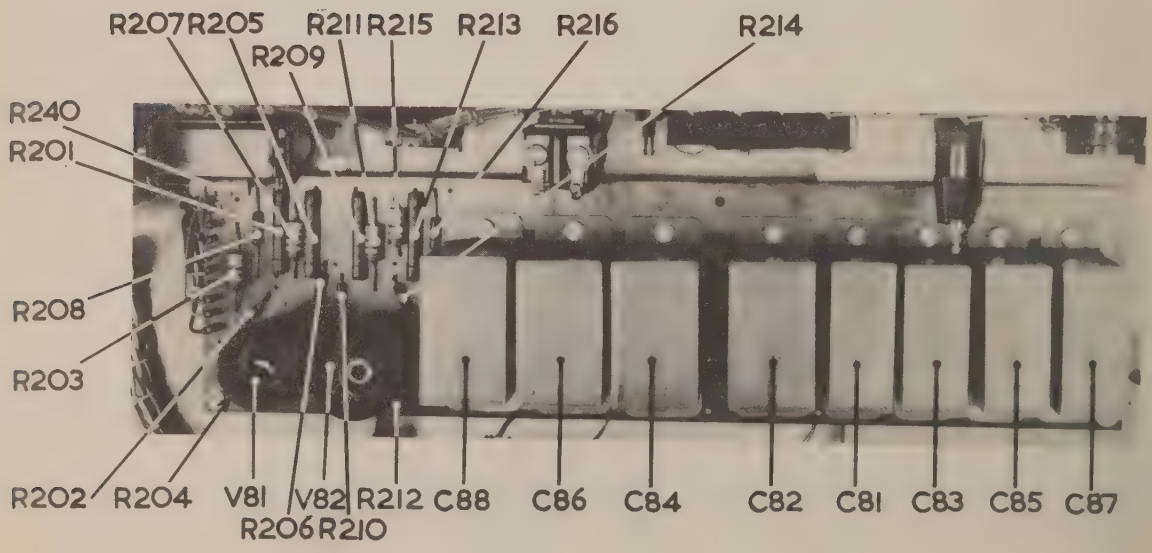


Plate 9: Sub-Unit 9

4.10. POWER SUPPLY

The circuit used in the power unit is composed of:—

1. A Stable Voltage Reference
2. A Sampling Chain
3. A D.C. Amplifier
4. Series Control Valves
5. An Unstabilised Power Supply

These are connected together as shown in the accompanying block diagram (Fig. 12).

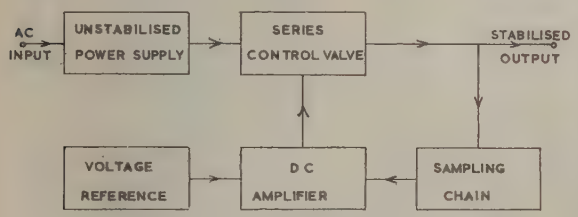


FIG 12

A proportion of any change which appears on the stabilised output is fed through the sampling chain into the D.C. amplifier. It is then amplified and fed to the grid of the series control valve. This alters the volt drop across the series valve in such a sense as to oppose the initial change. The final magnitude of the change is a function of the gain of the D.C. amplifier. The voltage reference is a Mullard 85A2 operating at a current of 6 mA approximately. This valve has a burning voltage of 85 V.

The sampling chain is a series of high stability carbon resistors connected between the stabilised H.T. + and H.T. —. It acts as a potential divider supplying signal to the D.C. amplifier.

The D.C. amplifier consists of two pairs of valves forming two cathode coupled differential amplifiers in cascade.

The first stage both halves of V6 compares a portion of the reference voltage with a portion of the H.T. voltage. The push-pull output of this stage is directly coupled to the second stage (both halves of V5) where further amplification takes place. The output from one side of the second amplifier controls the series stabilising valves.

First order compensation of D.C. drifts due to changes of heater voltage is automatic, since both sides of the differential amplifier tend to drift in the same direction, thus resulting in no output drift signal.

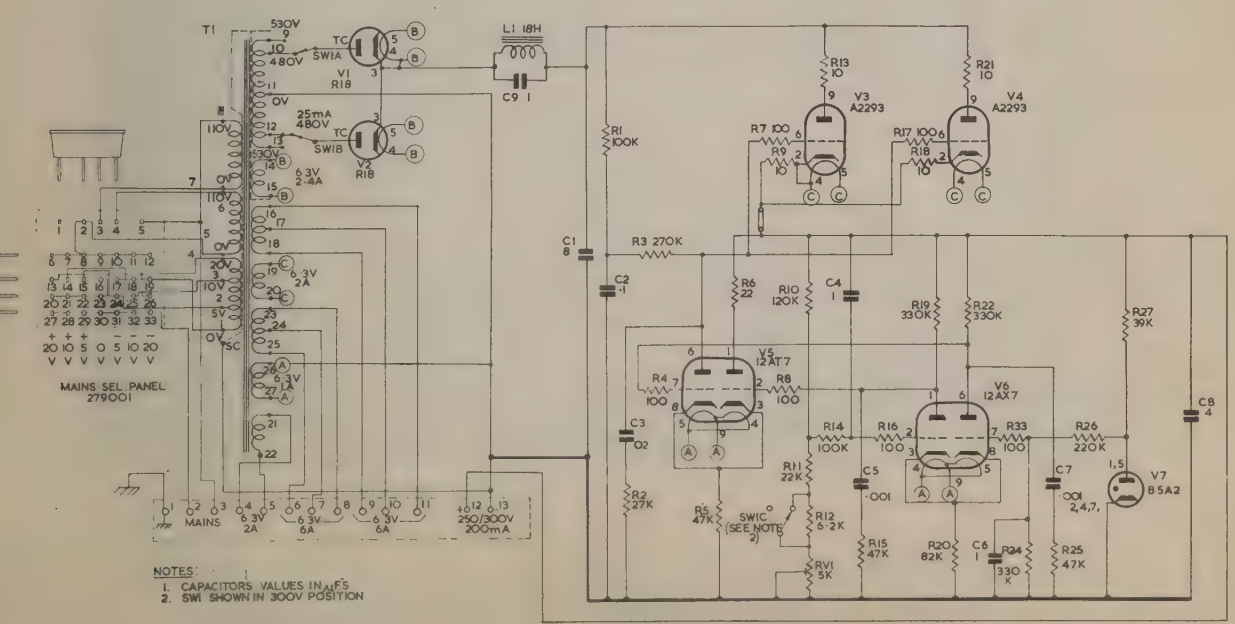
The series control valve carries the current drawn from the stabilised rail. Two A2293's V3 and V4 in parallel act as the series valve. They are fitted with anode and grid stoppers as a precaution against parasitic oscillation and resistors are connected in the cathodes to give some autobias and thereby aid load sharing.

The unstabilised power supply is of conventional form, consisting of a transformer feeding a full-wave rectifier and a choke input filter.

Performance Tests

Supply the unit with nominal mains, and correctly load all the A.C. and D.C. outputs. The voltage at the A.C. outlets should be $\pm 3\%$ of nominal. The D.C. potential can be accurately set by adjusting RV1.

Monitor D.C. stabilised line with a C.R.O. to ensure the absence of parasitic oscillations. Using an A.C. millivoltmeter check that the hum and noise



present on the D.C. output is less than that specified. The chassis should be earthed for this test.

Check that the changes of D.C. output are not measurable when the H.T. current is changed from full load to the permissible minimum, and when the mains input is varied $\pm 7\%$ about nominal.

The A.C. source impedance is measured by driving 5 mA A.C. into the stabilised output through a suitable capacitor, and measuring the A.C. potential across the output.

Quiescent Potentials

These potentials are supplied for information only and are not mandatory requirements. They were measured using an avometer, model 8, with its negative terminal attached to H.T. negative. The power supply sub-unit was operating at full load 300 V and supplied at nominal mains potential.

Valve No.	Pin No.	Meter Reading	Meter Range
V1 and 2	3	442	1000
V3 and 4	9	410	1000
V3 and 4	6	282	1000
V5	1	298	1000
V5	2*	185	250
V5	3 and 8	193	250
V5	6	282	1000
V5	7*	184	250
V5	1*	185	250
V6	2*	51	100
V6	3 and 8	52-2	100
V6	6*	184 V	250
V6	7*	48 V	100

* 12K resistor in series with the meter to prevent parasitic oscillation.

Table 9.

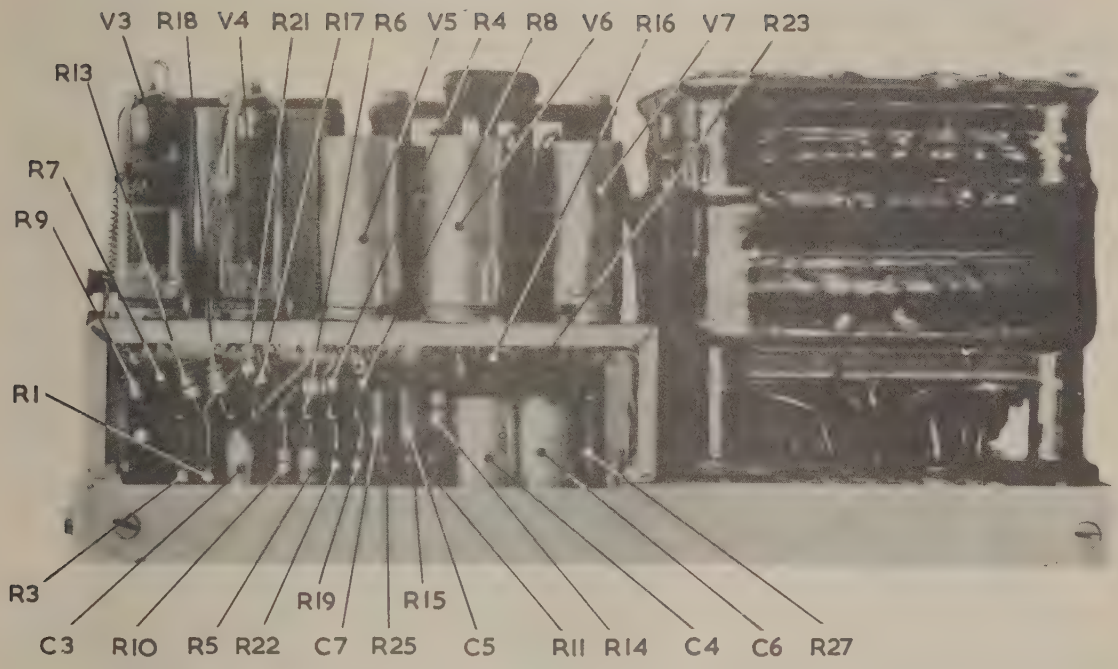
Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R1	100k	10	Erie	9 Carbon	¼	226349
R2	27k	10			¼	226342
R3	270k	10			¼	226354
R4	100	10			¼	226313
R5	47k	10	Erie	8 Carbon	¼	226545
R6	22	10	Erie	9	¼	226305
R7	100	10			¼	226313
R8	100	10			¼	226313
R9	10	10			¼	226301
R10	120k	1	Painton	73 H.S.	½	223692
R11	22k	2	Erie	109	⅛	221157
R12	6·2k	1			⅛	221044
R13	10	10		9 Carbon	¼	226301
R14	100k	1		109 H.S.	⅛	221073
R15	47k	10		9 Carbon	¼	226345
R16	100	10			¼	226313
R17	100	10			½	216313
R18	10	10			¼	226301
R19	330k	1	Painton	73 H.S.	½	223702
R20	82k	10	Erie	8 Carbon	¼	226548
R21	10	10	Erie	9 Carbon	¼	226301
R22	330k	1	Painton	73 H.S.	½	223702
R23	100	10	Erie	9 Carbon	¼	226313
R24	330k	1	Painton	73 H.S.	½	223702
R25	47k	10	Erie	9 Carbon	¼	226345
R26	220k	1		109 H.S.	⅛	221081
R27	39k	5	Painton	P305 W. W.	6	239044
RV1	5k	10	Colvern	CLR/1206/9S	½	256412

Circuit Ref.	Value µfd.	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C1	8	20	T.C.C.	CP150T Paper	600	211204
C2	0·1	20		CP46S	500	214207
C3	0·02	20		CP33N	350	214103
C4	1	25	Hunt	B509 P M.P.	250	206605
C5	0·001	10	T.C.C.	CSM20N Mica	350	N20098
C6	1	20	Hunt	B503 M.P.	150	206504
C7	0·001	10	T.C.C.	CSM20N Mica	350	N20098
C8	4	20		CP149V Paper	800	211303
C9	0·1	20		CP47W.	1000	214407

Circuit Ref.	Type	Description	Manufacturer
V1	R18	Rectifier	S.T.C.
V2	R18		
V3	A2293	Triode	G.E.C.
V4	A2293		
V5	12AT7	Double Triode	S.T.C.
V6	12AX7		
V7	85A2	Voltage Ref.	Mullard

Circuit Ref.	Description	Supplier	Type
T1	Transformer	Parmeko	295024
L1	Choke	Parmeko	292004



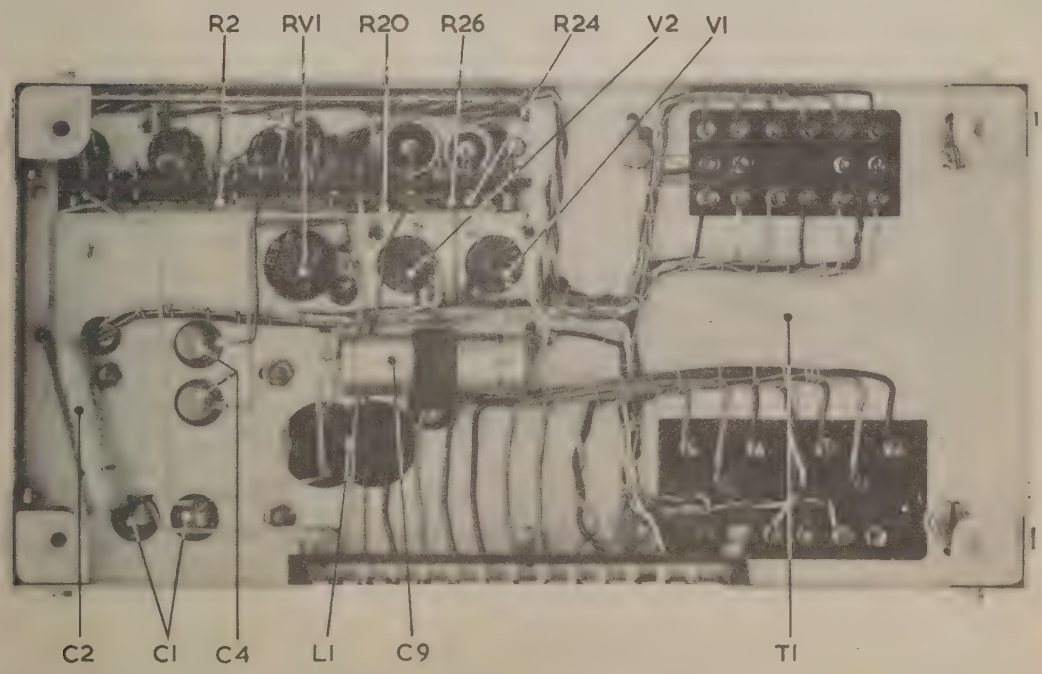


Plate 10: Power Supply

4.11. THE METER-CIRCUITS AND INTER-UNIT WIRING

The thermocouple wattmeter arrangement employed in the Resolved Component Indicator comprises two fixed resistors, two vacuo-junction thermocouples and a D.C. moving coil meter. The fixed resistors and vacuo-junction thermocouples are housed in the meter case, and the overall assembly is provided with four input terminals—see Fig. 2.

The fixed resistors and thermocouple heaters are all of equal resistance, but the value of this resistance may vary between 90Ω and 120Ω.

The fixed resistors and the thermocouple heaters are connected in Wheatstone bridge form, and the thermocouples are connected in series opposition to feed the moving coil meter.

The behaviour of this system is discussed in Appendix A.

The network of resistors external to the meters serves three functions: R232, R233 and RV91 serve to compensate for any slight unbalance in the ' in phase ' reference signal, RV91 being the reference meter datum control. R236, R237 and RV92 perform a similar function for the quadrature meter.

R231, R234, and R235, R238, are in series with the signal current to the meters. These resistors are provided so that the signal voltage output from the amplifiers may be large compared with any drift signal in the output amplifier. They also swamp the resistance of the thermocouples so that constant current will flow for any thermocouple resistance in the above-mentioned range. There are similar swamp resistors in the reference current paths, but these are mounted in the reference drive amplifiers. To equalise the sensitivities of the two meters, a portion of the swamp resistor in the quadrature channel is made variable (RV93A and B) and to give this a positive and negative sweep, R242 and R241 are connected in the ' in phase ' reference channel.

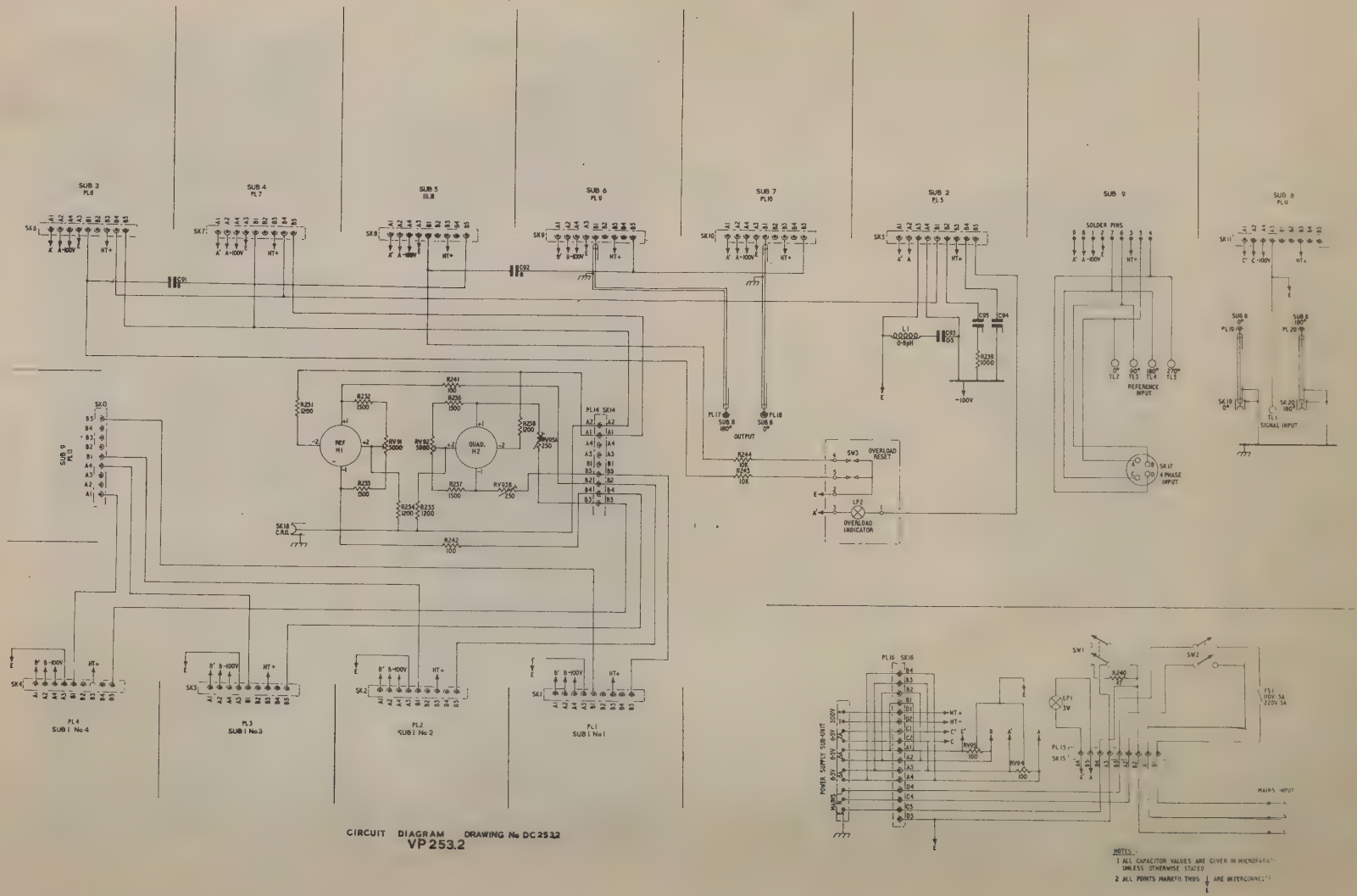
The main interconnecting wiring between sub-units is by means of a printed-circuit board running along the centre of the instrument. This carries all the sockets into which the sub-units plug, and a number of components are also mounted on it.

Components

Circuit Ref.	Value Ohms	Tol. %	Manufacturer	Type	Rating Watts	Solartron Part No.
R231	1200	2	Painton	73 H.S.	¼	223844
R232	1500	2			¼	223846
R233	1500	2			¼	223846
R234	1200	2			¼	223844
R235	1200	2			¼	223844
R236	1500	2			¼	223846
R237	1500	2			¼	223846
R237	1500	2			¼	223846
R238	1200	2			¼	223844
R239	1000	10	Erie	9 Carbon	¼	226325
R240	47	5	Welwyn	F5 MF.	2	235609
R241	100	10	Erie	9 Carbon	¼	226313
R242	100	10			¼	226313
R243	10k	10	Erie	9 Carbon	¼	226337
R244	10k	10	Erie	9 Carbon	¼	226337
RV91	5000	10	Colvern	CLR1206/9S W.W.	½	256412
RV92	5000	10			½	256412
RV93	250+250	10	Clarostat	43 dual W.W.	1	N25807
RV94	100	10	Colvern	CLR1206/9S W.W.	½	256407
RV95	100	10			½	256407
L1	·8 μHy/1					293001

Circuit Ref.	Value μFd	Tol. %	Manufacturer	Type	Rating Volts	Solartron Part No.
C91	8	20	Hunt	WP214 M.P.	150	N20125
C92	8	20			150	N20125
C93	5	25		B502	150	206503
C94	1	25		B503	150	206504
C95	1	25			150	206504

Circuit Ref.	Type	Description	Manufacturer	Solartron Part No.
SW1	8821/k5	Switch Toggle	N.S.F.	
SW2			Bonella	
SW3	80/10/14466	Switch, Push HF Transparent Red	Thorn	
FS1	L1055/3	Fuse	Belling & Lee	372275
TL1		Terminal		408461
TL2				408461
TL3				408461
TL4				408461
TL5				408461
LP1		Lamp M.E.S. 6·5V ·3 A		
LP2	X959119	Lamp Midget	Thorn	
M1		Meter (Reference)		341008
M2		Meter (Quadrature)		341007
PL12	MP9	Plug Micronector 9-way	McMurdo	
PL14				
PL15				
PL16	MP18	Plug Micronector 18-way	McMurdo	
PL17	UG260/U	Plug Coaxial	Transradio	
PL18				
PL19				
PL20				
SK1	MS9	Socket Micronector 9-way	McMurdo	
SK2				
SK3				
SK4				
SK5				
SK6				
SK7				
SK8				
SK9				
SK10				
SK11				
SK12				
SK13				
SK14				
SK15				
SK16	MS18	Socket Micronector 18-way		
SK17	CZ49221	Socket 4-way MK4 Pos O	Plessey	
SK18	UG447/U	Socket Coaxial	Transradio	
SK19				
SK20				



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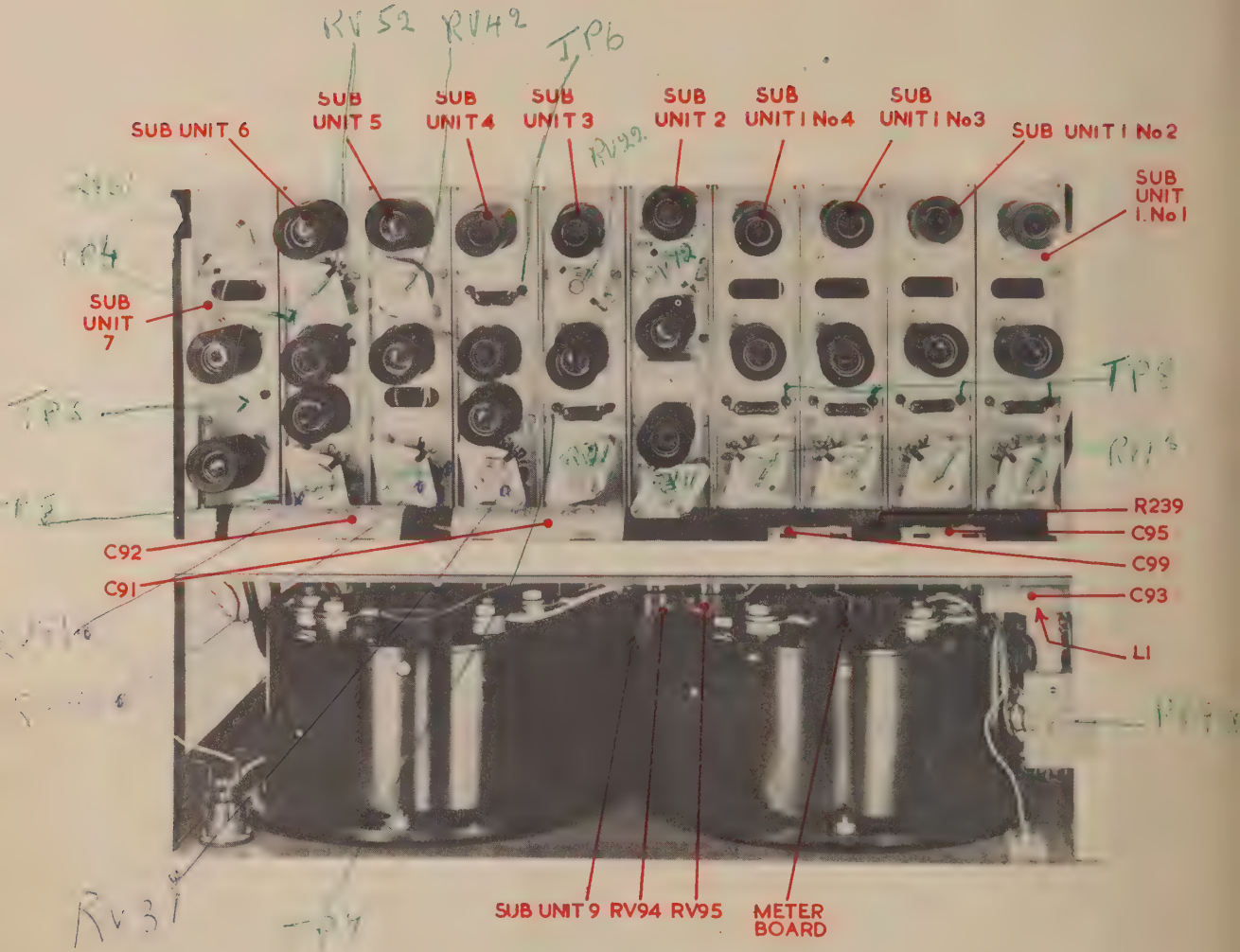

Plate 11: Complete Equipment

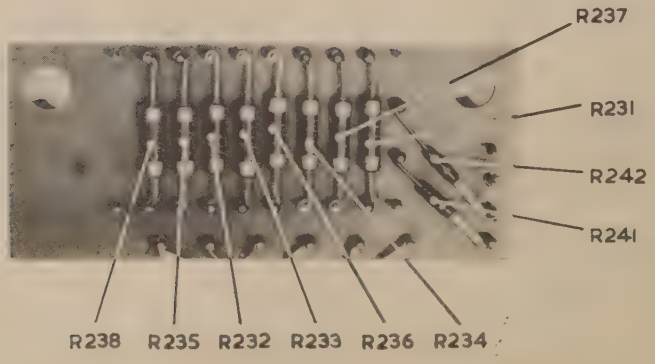

Plate 12: Meter Resistor Board

SECTION 5

MAINTENANCE INFORMATION

To remove the instrument from its case, remove the four panel-fixing screws at the sides of the panel, and the single screw through the bottom of the case at the rear. Open the door in the right-hand side of the case and check that the mains lead is not trapped. Withdraw the instrument from the case.

To remove any of the sub-units one to seven, unscrew the captive fixing screw which holds the sub-unit chassis to the main assembly, and withdraw the sub-unit from the rear of the frame. When replacing these sub-units, ensure that the plug on the sub-unit mates correctly with the socket on the main assembly.

To remove the power supply sub-unit remove the heat shield which is held in place by three countersunk screws through the back member of the frame, unplug the power supply from the socket attached to the front panel. Remove the four fixing bolts which hold the power unit to the bottom of the frame. The unit may then be removed through the rear of the frame.

To remove sub-unit 8, remove the sensitivity control knob and unscrew the balance, unbalance switch from the front panel. Unscrew four screws holding sub-unit 8 to the bottom of the frame. Disconnect four coaxial sockets and one micronector. Sub-unit 8 may then be withdrawn from the main frame. The side plates may then be removed to obtain access to the components. When all other sub-units have been removed, the meters may be withdrawn, and sub-unit 9 is then accessible. This may be unscrewed from the main frame, and removed after unsoldering connections to nine solder pins and unplugging the nine-way micronector.

As a guide during servicing, an abridged copy of the setting up and test procedure is given followed by a table of possible faults and a fault-finding procedure.

Setting-up Procedure

The following list of instruments is used in setting up and testing the equipment in the factory.

- E.I.L. Laboratory Sub-standard Voltmeter, Model 44.
- Avo Meter, Model 8.
- Solarscope models, CD513 or AD557.
- Solartron Oscillator CO546.
- Solartron Low Frequency Decade Oscillator OS103.
- Solartron Precision A.C. Millivoltmeter VF252.
- Solartron Calibrating Unit AT203.
- Thermocouple Milliameter to measure up to 20 mA r.m.s.
- Two dummy Thermocouple Wattmeters—see Fig. 15.
- Amplifier to provide 40 V and 100 V from a 10 V source—see Fig. 16.

During factory test, in order to protect the thermocouple meters against overload, dummy networks as shown in Fig. 15 replace the actual meters. Check that the mains selector panel is correctly set and that the sub-units have been replaced in their correct positions. Connect 0·1μFd capacitors of 150 V working in series with C91 and C92.

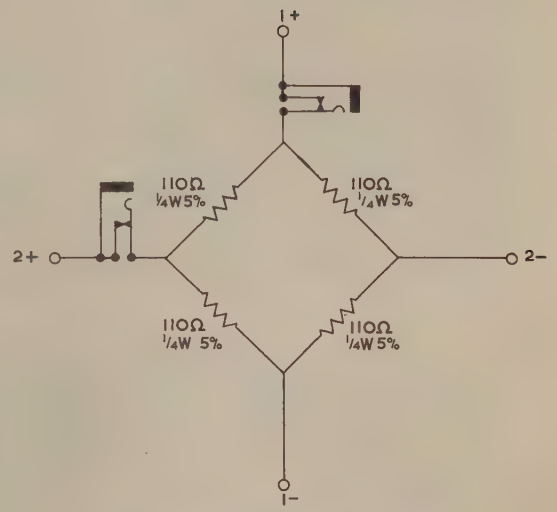

FIG. 15
DUMMY THERMOCOUPLE WATTMETER

Set the instrument controls as follows: to 'Prime', 'Balanced Input' and 'Direct Earth'.

Switch on the instrument and allow 15 minutes to warm up.

Check the H.T. supply to be 300 V ± 1% using a sub-standard meter. If necessary, adjust RV1 on the power supply sub-unit to obtain the required reading. Check that the − 100 V rail is accurate to ± 1% and if necessary adjust RV12 on sub-unit 2.

Connect an Avometer model 8 between the earth terminal and the following test points, adjusting the relevant potentiometers for zero D.C. on the 2·5 V meter range.

Sub-unit	*Test Point*	*Potentiometer*
S.U. 8	T.P. 1	RV71
	T.P. 2	RV72
S.U. 7	T.P. 3	RV61
S.U. 6	T.P. 4	RV51
S.U. 5	T.P. 5	RV41
S.U. 4	T.P. 6	RV31
S.U. 3	T.P. 7 or CRO. SKT.	RV22
S.U. 1 (4 off)	T.P. 8	RV1

Test points 1 and 2 are on the top of sub-unit 8 and are accessible from the left-hand side of the instrument.

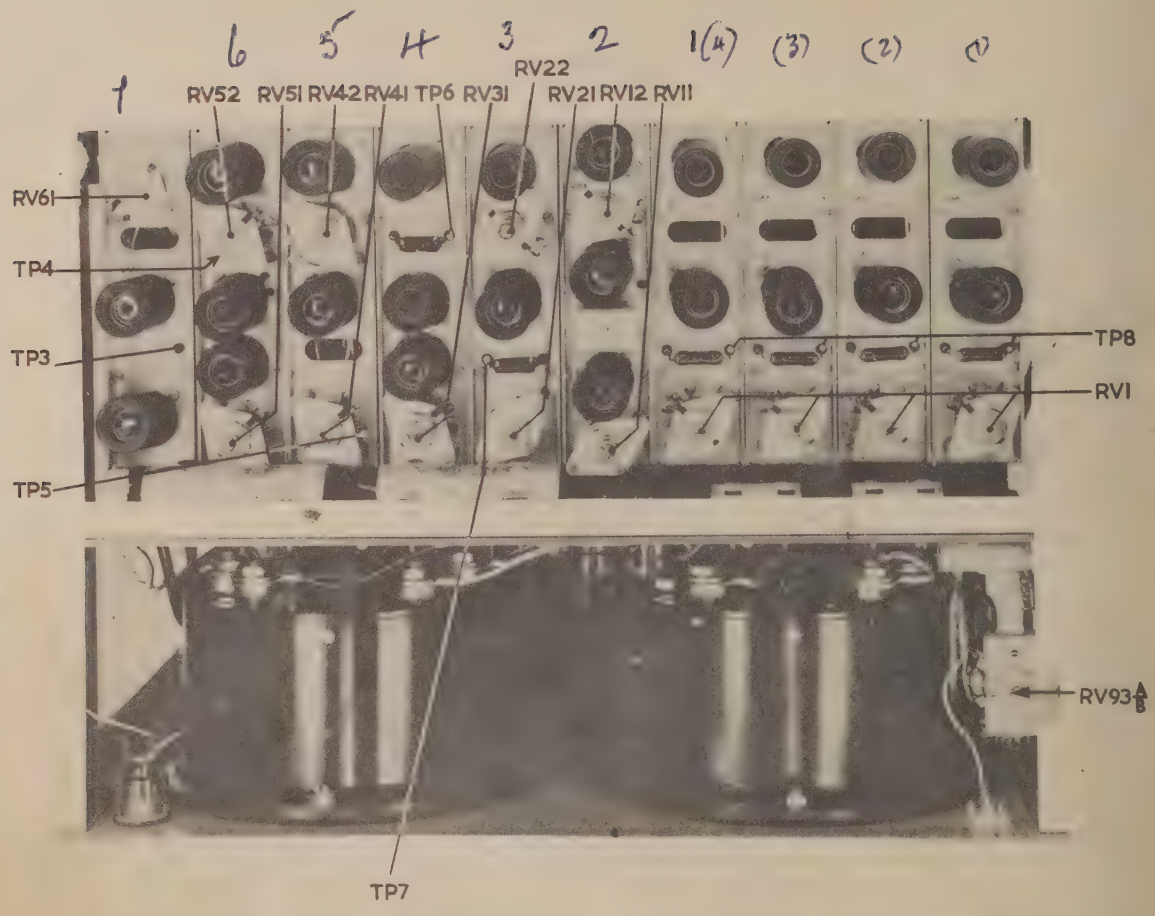

Plate 13: Complete Equipment. Pre-set Controls.

Initial Amplifier Settings

Set the VP253 sensitivity to 5 V and monitor the output at the C.R.O. socket with an A.C. millivoltmeter (VF252). Connect a 5 V r.m.s. 80 c/s signal from a wide range oscillator (CO546) to the 0° and 180° signal inputs simultaneously. Adjust RV52 for minimum indication on the A.C. millivoltmeter. This voltage is normally less than 100 millivolts.

Disconnect the 180° input and switch to unbalance. Adjust RV42 for an indication of 6·5 V on the A.C. millivoltmeter. Disconnect the oscillator.

Hum Balance Adjustments

Connect screened 1 MΩ resistors from the 0° and 180° input sockets to earth. Switch to ' Balanced ' and set the sensitivity control at 150 mV.

Adjust RV94 and RV95 for minimum output at the CRO socket as measured with the A.C. millivoltmeter.

Set the sensitivity to 50 mV and adjust RV73 for minimum output. Measure the hum under the input conditions shown and see that the figures do not exceed those recorded in the following table.

Range	Hum Outputs		Input Sockets
	Balanced	*Unbalanced*	
50 mV	30 mV	30 mV	Screened.
150 mV	12 mV	12 mV	1 MΩ resistors
500 mV	12 mV	12 mV	to earth.
50 mV	25 mV	25 mV	Short circuit to
150 mV	10 mV	10 mV	earth.
500 mV	12 mV	12 mV	

Signal Distortion and Overdrive

Set the instrument to ' unbalanced ' with the sensitivity control at 5 V. Connect a 5·V 80 c/s signal from an oscillator to the 0° input. Connect an oscilloscope (CD513) to the output of sub-unit 4. Connect the thermocouple milliameter in series with the 2 + lead of the dummy ' reference ' meter. Increase the input signal until distortion is just apparent on the peaks of the output waveform. The current in the thermocouple milliameter should not exceed 8 mA. Switch to the 50 mV sensitivity range and note that the current does not exceed 12 mA. Repeat this test with the thermocouple meter in series with the 2 + lead of the quadrature meter.

Reference Distortion and Overdrive

This test is similar to that which has just been described for the signal channel, but in order to get adequate signal to overdrive the reference channel, the test amplifier (Fig. 16) is used.

Set the test amplifier to × 10 balanced output and connect the two outputs to the 0° and 180° reference input terminals. Supply the test amplifier with a zero amplitude 80 c/s signal from the oscillator. Connect an oscilloscope to the output of sub-unit 1/2, and connect the thermocouple milliameter in series with the 1 + lead of the dummy reference meter. Switch the VP253 to ' Prime '. Increase the oscillator output amplitude until distortion is just visible on the output of sub-unit 1/2. Check that similar distortion appears on the output of sub-unit 1/3. The current in the thermocouple milliameter should be greater than 11 mA. Increase the oscillator output to maximum and check that the current reading is less than 17 mA. Connect the outputs of the amplifier to the 90° and 270° reference input terminals and repeat the above test measuring the current in the 1 + lead of the quadrature meter and monitoring the outputs of sub-units 1/1 and 1/4.

Overload Indicator

Set the VP253 to 5 V unbalanced input and supply a 5 V r.m.s. 80 c/s signal to the 0° input. Increase the signal amplitude to $\sqrt{2} \times 5$ V r.m.s. and adjust RV11 until the overload indicator flashes regularly. Make a final adjustment so that with 7·0 V input there is no overload indication and at 7·2 V input there is.

Reset the oscillator to 5 volts output and connect an oscilloscope to the C. R. O. socket. Increase the VP253.2 sensitivity to 50 mV and after a pause of 10 seconds return to the 5V range. The overload indicator will continue to flash at approximately 1 c/s and the oscilloscope will indicate severe distortion. Press the reset button for a few seconds and on release, the overload symptoms should have disappeared.

This completes the initial setting up.

The 0·1 μFd capacitors are now removed and C91 and C92 are reconnected in the normal way. The dummy meters are replaced by a pair of thermocouple wattmeters and the mechanical zeros of the meters are accurately set. The instrument is then switched on, allowed 15 minutes to warm up, and the D.C. and hum levels are checked. A 10 V, 80 c/s, four-phase reference supply is connected to the instrument by the four-core cable supplied.

Set the VP253 to 15 V unbalanced and connect the 0° input to each of the four reference phases in turn. Check that the deflection sense agrees with the accompanying table.

0° Socket to	*Meter Indication*
0° REF. TERMINAL	REF. in phase
90° ,, ,,	QUAD lead.
180° ,, ,,	REF. reverse phase.
270° ,, ,,	QUAD lag.

Meter Datum and Sensitivity Adjustments

Set the 10 V 80 c/s reference supply to precisely 10 V using an A.C. millivoltmeter calibrated against a substandard meter. Short circuit the signal input sockets to earth with the VP253 set to 15 V ' Balanced '.

Adjust the reference datum and quadrature datum potentiometers RV91 and RV92 to give an accurate zero on both meters.

Disconnect both input sockets from earth and connect both to the 0° reference terminal.

Adjust RV52 for an accurate zero on the reference meter.

Switch to unbalance and connect the 180° input to earth. Adjust RV42 to a reading of 10 V exactly on

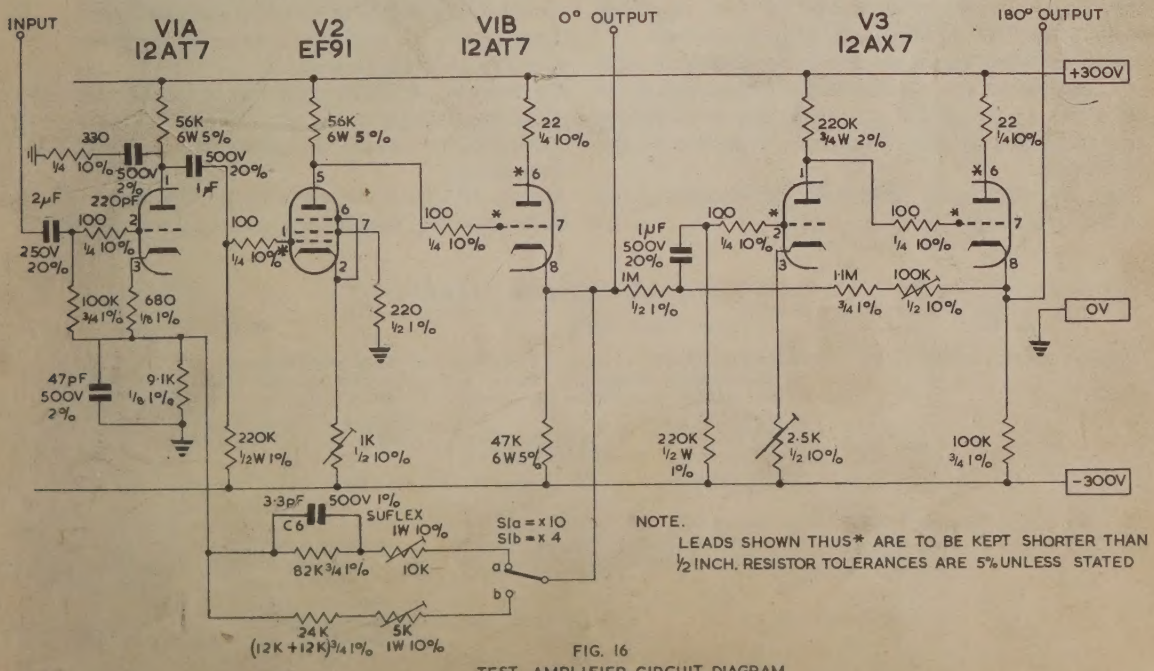

FIG. 16
TEST AMPLIFIER CIRCUIT DIAGRAM

the reference meter.
Connect the 0° input to the 90° reference terminal and adjust RV93 for a reading of exactly 10 V lead on the quadrature meter.

Performance Tests

The arrangement of test equipment required for performance tests on the VP253 is shown in Fig. 17.

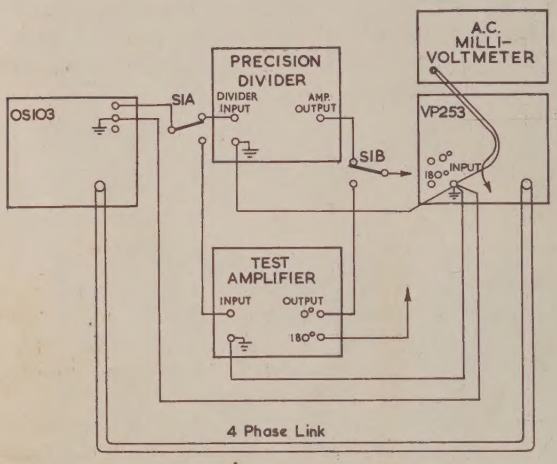

FIG. 17

The input signals are monitored by the A.C. millivoltmeter, which should be checked against a sub-standard meter. All test gear should be allowed 30 minutes to warm up.
Switch to balanced and supply an 80 c/s input signal from the 0° reference terminal to the 0° input with the 180° input earthed, and repeat the test supplying signal to the 180° input with the 0° input earthed.
Adjust the input signal amplitude in accordance with the table below, and check that the meter accuracy is better than ± 2% of full scale deflection on all ranges and better than ± 1% of full scale deflection on the 15 V range.
The quadrature meter reading should be zero ± 1% of full scale deflection.

Range	50 mV	150 mV	500 mV	1·5 V
Input	40 mV	100 mV	400 mV	1·0 V
Range	5 V	15 V	50 V	150 V
Input	5 V	10 V	40 V	100 V

Frequency Coverage

Connect the 0° input to the 0° reference terminal and the 180° input to earth, and set the VP253 to 15 V unbalanced. Reduce the input signal frequency to 0·5 c/s and adjust RV21 so that the quadrature meter swings symmetrically about zero. This swing should not exceed ± 1 V. The reference meter should not swing more than ± 2 V about the 10 V reading.
Switch the VP253 to 50 V balanced and, using the test amplifier, supply a 40 V 1 Kc/s input signal to the 0° input. Adjust C78 for minimum reading on the quadrature meter.
Select the 150 volt range and increase the input signal amplitude to 100 volts. Adjust C76 for minimum quadrature reading. Earth the 0° input and supply signal to the 180° input. Select, first the 50 V and then the 150 V range; supply signal inputs of 40 V and 100 V and adjust C74 and C72 for minimum quadrature signal.
Check the accuracy of the instrument at 1 Kc/s with input signals fed first to the 0° input and then to the 180° input, the unused input being earthed.
Using the following table of input signals, the reference reading should be accurate to better than ± 2% on all ranges, and the quadrature meter should read zero ± 1%.

Range	150 V	50 V	15 V	150 mV	50 mV
Input	100 V	40 V	10 V	100 mV	40 mV

Switch to 15 V balanced and set the test gear to supply a 5 V 80 c/s balanced input.
The reference meter reading should be 10 V ± 2% of full scale deflection, and the quadrature meter should read zero ± 1% of full scale deflection.
Connect the 0° input to a separate oscillator and switch to 15 V unbalanced.
Synchronise the signal oscillator to double and then triple the reference signal. Both reference and quadrature meters should read zero ± 0·1 V at both frequencies.
After a 30-minute warming up period, there should be less than 2% thermal drift over a period of 3 hours.

FAULT LOCATION CHART

SYMPTOMS	POSSIBLE CAUSE	REMEDY
Complete failure.	Open circuit fuse. No A.C. supply voltage. Mains voltage transformer in power supply sub-unit faulty. Open circuit wiring from mains voltage input to mains transformer primary primary winding.	Change the fuse. Measure the A.C. supply voltage applied to mains transformer primary winding. Measure the continuity and insulation of the transformer primary winding.
No indication on the meters with the unit switched on and warm.	The meters will not normally indicate unless both signals and reference inputs of suitable amplitude are applied to the unit.	1. Ensure that a 4-phase reference signal is properly connected via the 4-phase cable. 2. Connect the 0° signal input socket to the 0° reference terminal. Switch the input attenuator to the 15 V range. 3. Measure the 300 V high tension supply. 4. Measure the 100 V low tension supply.

(continued overleaf)

SYMPTOMS	POSSIBLE CAUSE	REMEDY
		5. Monitor the signal at Test Point 8 on sub-unit No. 1. 6. Monitor the signal at Test Point 6 and 7. 7. Monitor the signal at Test Point 5. 8. Monitor the signal at Test Point 3. 9. Monitor the signal at Test Point 2.
No 300 V high tension from power supply sub-unit.	Faulty regulator or rectifier valves. Short circuit on the high tension line. Faulty mains transformer. Faulty component in the regulator circuitry.	Change the valves in the power supply sub-unit. Measure the high tension line for short circuits. Measure the voltage applied to the rectifier anodes. Check the circuitry components of the power supply sub-unit.
Incorrect 100 V low tension from sub-unit 2.	Short circuit on the 100 V line. Faulty valve in the sub-unit V12B, V13. Faulty component in the unit circuitry.	Check the 100 V line for short circuit. Change the valves. Adjust slight errors with RV12. Measure other circuit components and change if necessary.
Incorrect signal at Test Point 8 on any of sub-unit type 1.	Fault in the relevant sub-unit. Fault in the corresponding input cathode follower on sub-unit 9.	Check input cathode follower by monitoring the signal on pin B1 of the sub-unit in the faulty channel. Change the valve and check circuitry if the cathode follower is faulty. Change the valves in sub-unit 1 and check circuitry for faulty components if necessary. Re-check the D.C. potential on TP8 after any repairs to the sub-unit.
Incorrect signal at Test Point 6 and 7.	This will indicate a fault in the signal amplifier chain.	Continue monitoring signals at Test Points in the order specified.
Incorrect signal at either Test Point 6 or 7 with correct signs at Test Point 5.	This will indicate a fault in one of the output amplifiers.	Change the valves in the faulty sub-unit. Check the D.C. level at the relevant test point. Check circuit components and change if necessary. Check meter circuitry. Check the coupling circuitry between Test Point 5 and input of the faulty unit.
Incorrect signal at Test Point 5 with correct signal at Test Point 3.	This will indicate a fault in the main signal amplifier sub-unit 5.	Change the valves V41 and V42 in sub-unit 5. Check the D.C. voltage on Test Point 5. Check circuit components in sub-unit 5 and change if necessary. Check the coupling from Test Point 3 to the input of sub-unit 5.
Incorrect signal at Test Point 3 with correct signal at Test Point 2.	This will indicate a fault in sub-unit 7.	Change the valves V61 and V62. Check the DC voltages at Test Point 3. Check the circuit components of sub-unit 7 and change if necessary. Check the coaxial coupling between Test Point 2 and the input to sub-unit 7. Check switch 72/4F on sub-unit 8.
Incorrect signal at Test Point 2.	This will indicate a fault in sub-unit 8, V72, or input switching, SW71/3R.	Change V72 and check its circuit component. Check the input switching circuit.
The 180° signal input amplifier on sub-unit 8 and 6 can be checked in a similar manner to the 0° signal input amplifier using Test Points 1 and 4 instead of 2 and 3.		
Residual reading on either meter with no inputs.	Faulty meter. Faulty high tension supply.	Change the meter. Check the high tension supply for correct voltage and hum level.
NOTE: Before a new thermocouple meter is fitted it is recommended that the unit is checked for normal operation using dummy meters—see Fig. 15.		
Residual reading on both meters with reference input only.	Faulty signal channel output amplifier sub-unit 6 or 7.	Check sub-units as before for D.C. voltages on the relevant test point.
Large meter swing at 25-100 cycles per second operation.	High tension rectifier faulty.	Change the valve.

The overload indicator is intended primarily to indicate an overload in the signal amplifier chain, which would not normally be indicated on the meters, such as an input with a high noise to signal ratio. In this case the meters would indicate only signal and the amplifier would be overloaded by noise. The CRO socket provides a means of monitoring to see the cause of the overload.

The overload indicator will, however, operate due to other causes such as excessive signal input and a positive change of D.C. voltage in sub-units 3 and 4. Still another reason for the indicator to operate could be a change of operating conditions or a change within a system under test. In this case, although the overload would be momentary, the overload circuit would reset and re-operate for some time due to the long recovery time of the VP253 circuit. Although the operation of the overload circuit does not change the circuitry of the amplifiers, any readings observed during an overload indicated period are not reliable and it is advisable not to continue tests for about one minute after the indicator has ceased to operate.

Failure of the overload circuit to operate on a known overload will be due to a fault in the overload circuitry and checks should be made of V11 and V12 and associated circuitry, particularly RL1 and its contacts.

APPENDIX A

The deflection of the thermocouple wattmeters used in this instrument is directly proportional to the product of the reference input and the 'in phase' component of the signal input. The circuit of one of these meters is shown in Fig. 2. If the four resistor arms are equal, then the current in thermocouple 1 is $\frac{I_e}{2} - \frac{I_s}{2}$, and the current in thermocouple 2 is $\frac{I_e}{2} + \frac{I_s}{2}$.

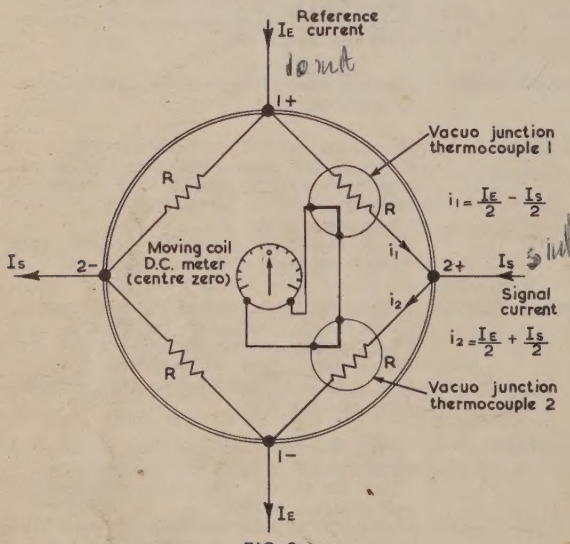

FIG. 2

The voltage elements of the thermocouples are in series opposition, and the voltage output of each is proportional to the square of the current in it. Thus the instantaneous voltage applied to the meter movement is proportional to

$$\left(\frac{i_e + i_s}{2}\right)^2 - \left(\frac{i_e - i_s}{2}\right)^2$$

i.e. K. i_e. i_s.

Where K is an arbitrary constant.

Assume i_e is of the form A sin ωt and i_s is of the form B sin pt.

Then the average meter deflection

$$= \frac{K}{t}\int_o^t A \sin \omega t \; B \sin pt \; dt$$

$$= \frac{KAB}{t}\int_o^t \tfrac{1}{2} \cos (\omega - p)\, t - \tfrac{1}{2} \cos (\omega + p)t \; dt$$

There are three cases which require consideration:—

a) when $P = \omega - \frac{\phi}{t}$

b) when $P = n\omega$ where ϕ is an arbitrary phase shift

c) when $P = \frac{n\omega}{m}$ n and m are arbitrary constants

In case a):

The integral simplifies to

$$\frac{KAB}{2t}\int_o^t \cos \phi - \cos(2\omega t - \phi)\; dt$$

This gives an average deflection over one cycle of

$$\frac{KAB}{2} \cos \phi$$

Thus, if the energising current is constant, the deflection is proportional to B Cos ϕ, the component of the signal current which is in phase with the reference current.

In case b):

The integral becomes

$$\frac{KAB}{2t}\int_o^t \cos (\omega - n\omega)\, t - \cos (\omega + n\omega)\, t \; dt$$

which gives an average deflection of zero over one cycle.

Thus, there is no deflection from any multiple of the reference current which may be present in the signal current.

In case c):

The integral becomes

$$\frac{KAB}{2t}\int_o^t \cos \left(\omega - \frac{n\omega}{m}\right) t - \cos \left(\omega + \frac{n\omega}{m}\right) t \; dt$$

There is now no direct harmonic relationship between ω and P and it can be shown that, over an infinite period of time, the average value of the integral is zero, except in the special case where m = n.

In practice, when Pt approaches ωt so that they are less than about 3 c/s apart, the meter needles will commence to 'beat' due to the lack of thermal inertia of the thermocouples.